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F-15 VIBRATION, SHOCK, ACOUSTIC AND ACCELERATION LOAD DESIGN REQUIREMENTS AND TEST PROCEDURES FOR AIRCRAFT EQUIPMENT - UPDATE BASED ON GROUND AND FLIGHT TEST MEASUREMENTS

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ABSTRACT

This report contains the vibration, shock, acoustic noise, and acceleration design load requirements for all equipment in all versions of the McDonnell Douglas F-15 aircraft. It also contains test requirements, test procedures, and test documentation requirements for this equipment. Requirements and test procedures for environmental stress screening and reliability development are also provided. Additionally, guidelines for design and test in support of the AVIP philosophy are presented.

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Symbols and Abbreviations

Symbol	Description
AMAD	Airframe Mounted Accessory Drive
AMRAAM	Advanced Medium Range Air-to-Air Missile
APU	Auxiliary Power Unit
ASAT	Air-launched Antisatellite
AVIP	Avionics Integrity Program
BL	Buttock Line
ctr	center
d.a.	double amplitude
ESS	Environmental Stress Screening
f	frequency
flt hrs	flight hours
FS	Fuselage Station
fwd	forward
JFS	Jet Fuel Starter
L	left
LANTIRN	Low Altitude Navigation and Targeting Infrared for Night
MCAIR	McDonnell Aircraft Company
MS	Missile Station
PS	Procurement Specification
PSD	Power Spectral Density
R	right
RDT	Reliability Development Test
rms	root mean square
SPO	System Program Office
Sta	Station
WL	Waterline

1. SCOPE:

This document presents updated vibration, shock, acoustic and acceleration load design requirements and test procedures for F-15 equipment to ensure structural integrity and proper operation of the equipment for the required service lifetime. The update is based on ground and flight vibration and noise measurements obtained on F-15A/B/C/D/E aircraft and laboratory test articles. The updated requirements apply only to procurement of new equipment items as specified in approved Engineering Change Proposals and they do not apply to equipment items originally procured to the requirements of Reference 1 or Reference 2 and its earlier revisions. The requirements provided in this document have been defined based on full F-15 flight envelope critical dynamic environments and actual usage times.

These requirements apply, in general, to all units and components of operating equipment. This includes, but is not limited to, relay panels, pumps, motors, valves and individually packaged units of the avionics, secondary power, hydraulic and electrical subsystems. They do not apply to structural components such as landing gear or weapon pylons nor to passive equipment items such as fuel cells. Documentation requirements for the tests defined herein are also presented.

Some equipment procured for the F-15 may have already been qualified to other specifications. Specific equipment and specifications will be addressed on an individual basis to determine the suitability for use without requalification to meet this document.

Vibration requirements are defined for the F-15 service lifetime by incorporating worst case non-buffet and buffet usage data. Performance design and test levels are maximum anticipated values, adjusted for laboratory testing, based on F-15 measured data. Endurance vibration levels are established from performance levels using time compression techniques to verify structural design adequacy for vibration exposure equivalent to the F-15 service lifetime of 8000 flight hours with a scatter factor of two.

Shock requirements and procedures are from MIL-STD-810E except as modified herein.

Acoustic noise requirements are defined for the F-15 in a manner similar to that used for vibration.

Acceleration loads requirements are defined for normal operating, limit and ultimate conditions based on F-15 full flight envelope capabilities.

2. APPLICABLE STANDARDS:

MIL-STD-810E Environmental Test Methods

MIL-STD-781C Reliability Testing for Engineering Development, Qualification and Production

3. DESIGN REQUIREMENTS:

The equipment shall be designed so that no fractures or permanent deformations shall occur, no fixed part or assembly shall become loose, no moving or movable part of an assembly becomes free or sluggish in operation, no movable part or control shifted in setting, position, or adjustment, and the performance shall be within the requirements of the applicable equipment specifications for the following conditions of vibration, shock acoustic noise, flow resonance and acceleration loads. Any deviation from the above shall constitute a failure.

3.1 VIBRATION:

All equipment shall be capable of satisfactory operation before, during and after exposure to all vibration environments existing on the F-15 aircraft. The aircraft vibration is primarily random in nature caused by engine exhaust on the ground and turbulent airflow in flight. Some exceptions to this are the sinusoidal vibration of engine and secondary power equipment and those items affected by gunfire.

Applicable design vibration levels are dependent on the equipment location in the air vehicle as presented in Figure 1. Random vibration requirements apply for all items except secondary power system equipment for which sinusoidal vibration requirements apply. Equipment locations affected by gunfire vibration are shown on Figure 36 and will include both random and sinusoidal requirements.

3.1.1 General Requirements. When normally mounted (with vibration isolators in place, if applicable) the equipment shall be designed to fulfill specified performance and endurance requirements when subjected to random or sinusoidal vibration shown by the test curves of Figures 2 through 17 for non-gunfire and Figures 37 through 49 for gunfire, as specified in the applicable equipment specifications. The test procedures to demonstrate compliance with these requirements are given in Section 4.

Performance or functional design requirements represent the anticipated worst case environment for any maneuver or condition in the F-15 flight envelope, adjusted for laboratory testing. Endurance design requirements are determined so as to provide a structural and functional life which is compatible with the aircraft service life usage requirements. Actual F-15 flight usage data have been used to determine the relationship between the performance and endurance design and test requirements. Signal Data Recorder tapes from various air bases were processed to define the actual aircraft usage during both non-buffet (level flight below 5 degrees angle of attack) and buffet (load factor maneuvers above 5 degrees angle of attack) flight conditions. The worst case single air base usage was used in the endurance level computation.

3.1.2 Minimum Structural Integrity. Minimum integrity vibration levels are not based solely on aircraft flight application environments. Rather, experience has shown that equipment which withstands these exposures functions satisfactorily in general field use and equipment tested to lower levels does not. These requirements are sometimes called "junk" levels and provide a reasonable assurance that equipment can withstand operations and handling during field installation, removal and repair.

All equipment shall be designed to withstand a minimum vibration environment. This applies to both normally mounted equipment and equipment removed from vibration isolators. The random vibration design and test requirements are shown on Figure 50. The procedures to demonstrate compliance with this requirement are described in Section 4.2.2.5.

3.1.3 Environmental Stress Screening. This requirement is intended to expose any weaknesses or latent defects prior to delivery of the hardware to the customer. This is done by changing an undetected defect into an observable failure which will be repaired prior to delivery.

All equipment shall be designed to withstand and to demonstrate performance during the Figure 51 environmental stress screening requirements. Stress screening test procedures are described in Section 4.2.2.6.

3.1.4 Reliability Requirements. Reliability development tests are required as defined by the equipment specification document to demonstrate satisfactory equipment reliability in an operational environment. Requirements for this test are defined in Section 4.2.3 and are shown on Figure 52.

3.1.5 Flightworthiness Requirements. Flight operations with certain equipment which has not been qualified to the F-15 environment must be designed and tested to demonstrate a flightworthiness capability. This would apply to situations like an experimental flight test program (prototype) or delivery of production hardware prior to completion of the qualification test program. The applicability of this requirement is not universal and must be assessed on a case by case basis or as defined by the equipment specification document. As a general rule, however, all items which deal with flight operations and/or flight safety will fall under this requirement. Demonstration of a flightworthiness capability is intended to provide coverage for up to 50 flight hours. Flight durations longer than this must be assessed on an individual basis and may require additional testing to demonstrate added capability. Flightworthiness test procedures are outlined in Section 4.2.2.9.

3.1.6 Pods and Weapons. Vibration design levels for externally carried weapons and electronic pods are based on measurements made on specific items (i.e. LANTIRN Pods, AMRAAM Missile, etc.). These levels are provided as a design guide if no other data is available for carriage on the F-15. Because of the complex mechanical/aerodynamic excitation and weapon/pod dynamic response, actual flight measured environments during captive carriage on an F-15 are recommended to establish final design and qualification/reliability test levels for weapon/pod structure and equipment. Vibration levels from various weapon/pod test programs are provided on Figures 18 through 35. These are based on part on the data reported in References 3 through 9.

3.1.7 Avionics Integrity Program (AVIP). Some avionics equipment, as defined by the individual procurement specification will be required to be designed using the AVIP philosophy. This process requires that all equipment components, down to the smallest electronic chip leads and solder joints, be designed and analyzed/tested to withstand the various stress cycles due to environmental changes without failure for an economic lifetime. Environments such as thermal, steady state loads, vibration, acoustic noise, shock, etc. result in cyclic stresses which must be considered along with the number of repetitions or amount of time at various levels. In order to support this design process, aircraft flight vibration exposure levels and times are provided in Figure 53 based on Signal Data Recorder records of F-15E usage. Figures 54 and 55 identify the Mach and altitude conditions that generate the vibration in Figure 53 for non-buffet and buffet levels.

Aerodynamic heating calculations may be used to determine skin temperatures from the Mach numbers in Figures 54 and 55 for external stores. The combined fatigue effects of vibration and the other environments on life are tested or analyzed in accordance with an AVIP Master Plan worked out between the user and suppliers.

3.1.8 Isolation Systems. As a design goal, all equipment is preferred to be normally mounted (without isolators) in the aircraft in order to minimize weight and cost. However, if the equipment cannot survive the applicable dynamic environment, an isolation system may be used if sufficient space is available in the aircraft, with the agreement of the buyer. If a resilient mounting system is to be used, it shall be so designed as to result in a resonant frequency between 20 and 30 Hz with the equipment installed on it. A center of gravity (c.g.) type mounting system is recommended to minimize the severity of vibration response at the isolator resonance frequencies. Base mounted isolation systems (non c.g. type) should only be used as a last resort as they produce additional rotation vibration at frequencies which may coincide with aircraft structural resonant frequencies. Unit vibration mounts shall use elastomeric resilient elements having sufficient stiffness in all axes to prevent bottoming or impacting with snubbing elements of the mounts under all design maneuvering and service shock conditions of the aircraft.

The transmissibility characteristics for a c.g. type isolation system are shown on Figure 56. These should be used to adjust the appropriate normally mounted vibration curve to compensate for the effect of the isolation system. Note that the transmissibility values of the curve must be squared in order to apply to random vibration PSD levels. In cases where base mounted systems are used, the buyer's dynamicist will provide the appropriate transmissibility curve.

3.2 ACOUSTIC NOISE:

All equipment shall be capable of satisfactory operation both during and after exposure to acoustic noise environments on the F-15 aircraft. Acoustic noise zones are shown on Figures 58 and 60. The equipment, in both non-operating and operating conditions, shall be designed to withstand exposure to a wide band noise spectrum of overall intensity and relative noise distribution shown on Figures 59 and 61. The procedure for the test to demonstrate compliance with this requirement is described in Section 4.3. Testing is not required for equipment in areas where the noise level is less than 140 dB OASPL.

3.3 SHOCK:

Mechanical shock is not normally an environmental condition during the functional life of the airplane except as gunfiring shocks effect items of the gun system, as store ejection shocks effect bomb racks and associated equipment and in cases where vibration isolators may bottom. Design requirements should be defined to ensure that equipment is capable of withstanding shipping, handling, installation and aircraft operation without damage to the unit or it's functional operation. General shock test requirements are presented in Section 4.4 along with guidelines for exempting this requirement in areas of severe vibration environments.

Design and qualification to either half-sine or sawtooth waveform shock pulses is permitted. Previous F-15 requirements (see References 1 and 2), which were based on earlier versions of MIL-STD-810, specified the half-sine shock waveform. The sawtooth shock waveform is specified in MIL-STD-810E.

3.3.1 Service Shock. The equipment shall be designed to operate within specified performance requirements when subjected to impact shocks in opposite directions along each of three orthogonal axes. Figure 63 identifies the various shock regions of the aircraft. The waveform and amplitude of the shock impulses shall be as specified for service shock in Figure 64. The number of shocks and test procedures to demonstrate compliance with this requirement are described in Sections 4.4.1, 4.4.2 and 4.4.3.

3.3.2 Crash Safety Shock. Internal equipment which, if loose, would endanger the crew must be designed to withstand crash safety shocks in opposite directions along each of three orthogonal axes, with excursion stops or bumpers in place. The shock impulse waveform and amplitude shall be as specified for crash safety in Figure 64. Bending and distortion are permitted, but the equipment must remain captive. The number of shocks and test procedures to demonstrate compliance with this requirement are described in Section 4.4.4. Use of a dummy load, in place of components mounted to the unit chassis, is permissible.

3.3.3 Transit Drop Shock. This requirement is intended for equipment in its transit or carrying case such as data storage devices, cryptographic devices or other items carried to the aircraft by the aircrew. This requirement is used to determine if the item is capable of withstanding the shocks normally induced by loading, unloading and dropping the equipment. The number of shocks and test procedures are described in Section 4.4.5.

3.4 EQUIPMENT ACOUSTIC NOISE GENERATION:

Equipment located in and around the cockpit must be designed so the noise generated while operating does not adversely impact the cockpit noise levels. The maximum allowable noise which may be generated by equipment is presented in Figure 62. The applicable curves of this figure shall be defined in the applicable equipment specification. These specified maximum acoustic noise levels are not to be exceeded at a distance of two feet from the equipment for any of the normal operating modes of the equipment. The test procedure to demonstrate compliance with this requirement is described in Section 4.5.

3.5 FLOW RESONANCE:

Any equipment in which high velocity fluid flows, such as components of the air conditioning system, must be designed to withstand any flow induced resonances. The test procedure to demonstrate compliance with this requirement is given in Section 4.6.

3.6 ACCELERATION LOADS:

All equipment in the aircraft shall be designed for the transient and steady-state accelerations which occur during flight, landing, take-off and ground handling operations. Maximum and minimum normal operating, limit, and ultimate load factors versus aircraft location are presented in Figures 66 through 71. Acceleration load factor requirements were developed for the various operating conditions. Designing to these requirements will assure that the equipment can structurally withstand the acceleration forces that are expected to be experienced in the service environment, and function without degradation during and following exposure to these forces. These are intended to be used only as a preliminary design guideline. Loading conditions for qualification of specific equipment items will be determined on an individual basis.

3.6.1 Normal Operating Load Factors. Normal operating loads include those loads developed during full envelope flight conditions, but not including spins or crashes. All equipment shall be capable of withstanding the applicable normal load factors without structural failure or loss of function. Trends of variation in normal operating load factor with equipment location are shown in Figures 66, 68 and 70. The equipment must demonstrate specified performance before, during and after this test.

3.6.2 Limit Maneuver Load Factors. Limit maneuver loads include all normal operating loads plus loads obtained during spins and crash landings. All equipment shall be capable of withstanding the applicable limit load factors without structural failure or functional damage. Trends of variation in limit load factors with equipment location are presented in Figures 67, 69 and 71. For equipment packages weighing less than 20 pounds, a limit load factor of plus or minus 10 g's applied individually along the three axes shall be used unless exceeded by the specified limit load factors. Some degradation of operational accuracy may be permitted during the application of these loads, but full accuracy must be demonstrated before and after application of these loads. No detrimental deformation is permitted which would:

a. Inhibit or degrade the mechanical operation of the airplane.

b. Affect the airplane's aerodynamic characteristics to the extent that performance guarantees or flying qualities requirements cannot be met.

c. Require repair or replacement of parts.

3.6.3 Ultimate load Factors. All equipment installation packages and associated mounting provisions shall have sufficient static strength to withstand, without structural failure at least the limit load factors multiplied by 1.5. For equipment weighing less than 20 pounds, the installation shall have sufficient static strength to withstand 15 g's acting individually along the three axes or the specified limit load factors multiplied by 1.5, whichever is greater. Equipment will not be required to function after being subjected to the ultimate loading conditions specified above. Bending and distortion of the equipment is permitted, however, there shall be no structural failure which causes the equipment to come loose from its mounts.

3.6.4 Crash Landing Load Factors. Equipment located in the crew compartment, such that structural failure of the equipment or its mounting would endanger the crew in event of a crash landing, shall have sufficient static strength to withstand, without structural failure, the following ultimate load factors, acting individually:

(a) A longitudinal load factor of 40 g's in all forward azimuths within 20 angular degrees from the longitudinal axis.

(b) A vertical load factor of 20 g's directed downward, normal to the longitudinal axis.

(c) A lateral load factor of ±10 g's normal to the longitudinal axis.

Fuel tanks, engines, armament items, and other large equipment items carried internally shall have sufficient static strength to withstand, without structural failure, the following ultimate load factors, acting individually:

(a) A longitudinal load factor of 9 g's acting forward and 1.5 g's acting aft.

(b) A vertical load factor of 2 g's acting up and 4.5 g's acting down.

(c) A lateral load factor of ±1.5 g's.

Equipment will not be required to function after being subjected to the crash landing conditions specified above. Bending and distortion of the equipment is permitted, however, there shall be no structural failure which causes the equipment to come loose from its mounts. Use of a dummy load, in place of components mounted to the unit chassis, is permissible.

4. QUALITY ASSURANCE REQUIREMENTS:

This section describes the methods which will be used to verify that aircraft equipment will maintain its structural integrity and will operate satisfactorily when exposed to vibration, acoustic noise, shock and acceleration environments. All equipment procured for use in the F-15 aircraft must be qualified by the applicable quality assurance methods and procedures as defined herein. The procurement specification shall define the equipment item qualification requirements including sufficient data to provide a realistic set of environmental requirements, instructions whether or not operation during testing is required, and the requirements for continuous or cyclic rate of operation during testing, length of test, test sequence, etc.

4.1 Definition Of Qualification. Equipment and components shall be qualified to the requirements of Section 3, herein, by test, similarity, analysis or a combination of these as outlined below and as required by the procurement specification.

4.1.1 Test. Test is defined as a procedure to verify that a specification requirement is met by a thorough exercising of the equipment or component under appropriate conditions in accordance with specified test procedures, herein. The equipment shall be subjected to a qualification test in accordance with the procurement specification if the equipment is a new design and the requirements of 4.1.3 are not applicable. Off-the-shelf and modified equipment shall be subjected to test if the requirements of 4.1.2 and 4.1.3 are not applicable.

Performance of tests is described in Sections 4.2, 4.3, 4.4, 4.5, and 4.6 for vibration, acoustic noise, shock, acoustic noise generation, flow resonance and acceleration respectively.

4.1.2 Similarity. Qualification by similarity is defined as the process of using test data from a previously developed and qualified item which meets the following requirements:

(a) The equipment is to perform the same function in the same application as it did in its earlier application and is similar in design, weight, materials and dynamic behavior.

(b) The environment and operating limits shall be no more demanding or degrading than in the earlier application.

(c) The new item does not incorporate significant differences that would invalidate the criteria of (a) or (b).

(d) The equipment operated satisfactorily in its earlier application as indicated by its mean time between failure (MTBF) field data and/or its earlier qualification test.

A modified equipment item shall be considered dynamically similar to the baseline item when all of the following apply:

(a) The total change in mass of the unit and each subassembly is within ±10%. The center of gravity is within ±10% of the original location in any direction.

(b) The mounting configuration is unchanged. The mounting configuration of circuit cards is unchanged.

(c) The first 3 natural frequencies of the chassis and the first natural frequency of each subassembly are within ±5% of the original frequencies. The first natural frequency of each circuit card is within ±10% of its original frequency.

(d) Each modified circuit card is vibrated for 1 hour in the axis perpendicular to the plane of the circuit board to the minimum structural integrity levels of Figure 50. Electrical continuity throughout the card shall be maintained during and after the test.

(e) Changes of mounts, chassis, internal support structures, and circuit card materials are to materials with equal or greater high cycle fatigue strength.

When qualification by similarity is proposed, the test data from the earlier qualification must be submitted with design data to substantiate the above requirements. Equipment previously qualified by test and approved for installation on other aircraft and meeting the above mentioned criteria, may be accepted without further testing.

4.1.3 <u>Analysis</u>. Analysis is defined as verification that a specification requirement has been met by technical evaluation of equations, charts, reduced data, and/or representative data. Equipment shall be qualified by design analysis where it clearly shows satisfactory performance under influence of the critical environmental parameters in accordance with the procurement specification.

4.2 <u>Vibration Test Requirements</u>. Vibration testing is performed to determine the resistance of equipment to vibrational stresses expected in its application, shipping and handling environments. This section establishes the laboratory vibration test procedures and test levels for testing equipment subjected to the environment associated with the F-15 aircraft.

4.2.1 Vibration Tests - General. Vibration tests are required to demonstrate the equipment's ability to provide satisfactory operation throughout the service life of the aircraft. The required vibration tests consist of five parts as follows:

a. A performance test is used to demonstrate that the equipment will provide specified performance during normal aircraft operation. The requirements for a separate performance vibration test may be waived if specified performance can be demonstrated during the more stringent endurance vibration test.

b. An endurance test is used to demonstrate that the equipment will provide the specified performance throughout the life of the aircraft without any failures.

c. For equipment located in the aircraft regions affected by gunfire environments, an additional performance vibration test is required. Equipment must demonstrate specified performance during this test unless otherwise stated by the applicable Procurement Specification.

d. An environmental stress screening vibration test is required to demonstrate that the unit will provide specified performance during exposure to the screening environment used on all production units prior to shipment from the manufacturer. Requirements for this test may be waived if specified performance can be demonstrated during the more stringent minimum integrity test.

e. A minimum integrity test is required to establish a capability to survive exposures to general field service usage environments of shipping and handling in addition to the aircraft operating environment. Specified performance need not be demonstrated during this test. Requirements for this test may be waived if the minimum integrity vibration level is less than the endurance level at all frequencies.

4.2.1.1 Test Setup. The test setup shall be planned with the actual aircraft application in mind. The test fixture and method of attachment shall simulate the aircraft installation as close as practical within reasonable limits.

4.2.1.1.1 Test Fixtures. Test fixtures shall simulate the actual service installation, as much as possible. They shall include excursion stops, electrical cables, and all other connections required for proper operation of the equipment. The location of these items shall simulate the service installation.

Any structural resonance of the test fixture within 20% of an equipment resonant frequency, with the test specimen installed, shall be adjusted such that the effect of these resonances on the vibration input shall be minimized. This is accomplished if, at these resonances, the vibration amplitudes at all equipment mounting points on the fixture are within $\pm$ 25% of the average of the amplitudes at all these points. This average shall be used to establish the test level.

Allowance shall be made for mounting fixture mechanical impedance effects whenever the benefits of increased realism are worth the time, effort and cost required for implementation. Use of this must be coordinated with the buyer's structural dynamicist.

4.2.1.1.2 Method of Attachment. The test specimen shall be attached directly to the vibration table or to an intermediate structure (fixture) which is so designed as to be capable of transmitting the specific magnitudes of vibration to the points of specimen attachment throughout the required frequency range. The mounting shall simulate service installation orientation including all vibration mounts and other holding devices plus all electrical cables and any other connections required for normal operation. Whenever possible, the test load shall be uniformly distributed in order to minimize the effects of unbalance loads.

4.2.1.1.3 Transducer Mounting. Input control sensors shall be rigidly attached to the test fixture as near as possible to the equipment attachment points. Response vibration sensors shall be attached to equipment primary structure and on internal components such as circuit boards, large components and modules, where practical. Sensor size, mass and location shall be selected to minimize effects on dynamic response.

4.2.1.2 Sequence of Tests. The applicable equipment specification shall define the sequence of tests performed on a single unit. The accumulated effects of vibration-induced stress may affect equipment performance under other environmental conditions, such as temperature, altitude, humidity, leakage or EMI/EMC.

It is required that the cumulative environmental fatigue effects of vibration and the other dynamic environments of shock and acoustic noise be evaluated. For this reason, a single test unit must be used for exposure to vibration, shock and acoustic environments. The sequence of these three tests can be in any order, however, due to the historically higher risk of passing the vibration test without failure, and thus requiring a retest, it is recommended that the vibration test be conducted first.

4.2.1.3 Performance Record. Prior to conducting environmental tests, the test item shall be operated under standard ambient conditions to obtain data for determining satisfactory operation of the equipment during and/or following the test. A pretest record shall be made to determine that the item performs within the tolerances defined in the procurement specification. A record of functional parameters to be monitored during the test shall be made including acceptable functional limits to be allowed during the test when operation of the item is required.

4.2.1.4 Test Tolerances. Accuracy of the laboratory test equipment used to conduct the test shall be verified periodically and must be within the required calibration date. The vibration amplitude tolerance must be with +20% and -0% or both sinusoidal and random overall vibration levels. The random vibration power spectral density shall be ±3 dB across the entire frequency band. However, deviations of up to -6 dB in the test control signal may be granted for frequencies greater that 500 hertz due to fixture resonance, test item resonance, or facility limitations. The cumulative bandwidth over which this reduction shall be allowed cannot be greater than 5% of the test frequency range. The vibration frequency tolerance must be with ±2%.

Tolerances for acoustic noise testing are shown on the Figure 59 and 61 frequency spectrums. The overall acoustic noise level must be within +4 and -0 dB of the specified overall level.

4.2.1.5 Inertia Relief. To account for a reduction in local vibration due to heavy weight equipment, the vibratory acceleration input to equipment weighing more than 80 pounds may, in some cases, be reduced according to the schedule defined on Figure 57. The applicable frequency range of this reduction is above 30 Hz. Frequencies below this are related to primary aircraft structural resonant modes and vibration levels are not significantly effected by the weight of equipment items.

This reduction can, however, only be used in cases where the vibration requirements were defined based on data without the heavy weight equipment installed in the aircraft. Because most test requirements are based on measured data obtained with the appropriate equipment in the aircraft, the usage of inertia relief may be limited. As a general rule, use of inertia relief is not applicable unless specifically noted in the equipment specification document. Inertia relief does not apply to equipment which is mounted on vibration isolators, nor does it apply to minimum integrity or environmental stress screening tests.

4.2.1.6 Test Axes. Unless otherwise stated in specific procedures, test items shall be vibration excited along three orthogonal axes corresponding to the vertical, lateral and longitudinal aircraft axes.

4.2.1.7 Input and Response Controlled Tests. Input control is the traditional approach to vibration testing. This test method utilizes the input vibration from the aircraft which is transmitted into the equipment carried by the aircraft. This test method is applicable except where equipment mass loading could significantly alter the environment or when the actual service excitation is applied to all parts of the equipment through multiple sources simultaneously (i.e., aerodynamic turbulence along a large component) rather than through a few distinct attachment points.

For input controlled tests, the specified vibration test levels shall be maintained at the points of equipment attachment. The transverse motion of the input monitoring points shall be minimized and must never exceed the input motion. For large test specimens, several transducers shall be used to monitor the input at each attachment point. Regardless of the number of input transducers used, the continuous and simultaneous average shall be that of the specified test curve. For sinusoidal tests, the average shall be based on the absolute scalar magnitudes of the input transducer levels and a tracking filter may be used in the control loop. For random tests, the power average of the input transducers shall be used. The instantaneous random vibration acceleration peaks may be limited to three times the rms acceleration level. The rms acceleration level shall not be less than the specified minimum level. Resonant modes of the moving mass (vibration exciter moving element, fixture and either the test item or substitute equivalent mass) shall be equalized or compensated for within the frequency range of the test curve.

Response controlled testing uses an essentially undefined input and instead tries to achieve an equipment structural response representative of that measured in a service environment. This approach is appropriate when actual vibration measurements exist and close correlation between laboratory and service conditions is readily achieved.

Input control testing applies to almost all equipment on the F-15 and should be used if no actual response measurements are available. In cases where response vibration data has been obtained, a response controlled test may be advisable to more closely approximate the real aircraft/equipment environment. Typical examples of this are externally carried weapons/pods and equipment mounted on other equipment such as the electrical generator mounted on the Airframe Mounted Accessory Drive (AMAD). Input control test methods should be used unless defined otherwise by the procurement specification.

4.2.1.8 Success Criteria. The equipment shall have passed the test successfully upon completion of all requirements without any failures.

4.2.1.9 Failure Criteria. When any of the following occur, the item shall have failed the test:

(a) Monitored functional parameters deviate beyond acceptable limits established for the equipment.

(b) Catastrophic Failure - Normally this is an irreversible failure caused by such conditions as a component burning out, burning up, breaking within the test item or cracking or breaking of the test item cover or mounting system.

(c) Degradation such as mechanical binding, mechanical wear(including chafing and fretting), loose parts (including screws, clamps, bolts or nuts), leaking and electrical arcing.

(d) Malfunction.

(e) Degradation of performance or any additional deviations from acceptable criteria established before the test and recorded in the pretest performance test.

4.2.1.10 Corrective Action/Retest After Failure. When a failure occurs, the cause shall be determined by investigation and analysis. This process shall include any applicable method which may be necessary to determine the cause of failure, such as careful laboratory trouble shooting procedures to identify the failed components, X-ray analysis, chemical analysis, microsectioning, or spectrograph analysis. Once the cause of the failure is defined, corrective action shall be accomplished, whether simple repair, replacement by a higher strength or higher rated part, or a minor or major redesign. Corrective action shall be verified as follows:

(a) When the failure occurred during the test and the testing was suspended, make the corrective action and compete the test. Continue with a repeat of the test through the time and condition at which the failure occurred, without failure of the corrective action. Any failures of items other than the corrective action during the retest are considered irrelevant.

(b) When the failure was found at completion of the test, retest the item without failure of the corrective action.

4.2.2 Vibration Tests - Detailed Requirements. This section establishes laboratory test procedures and levels for equipment subjected to the environment associated with the F-15 aircraft. The procedures described herein are to be utilized in accelerated tests of equipment to demonstrate satisfactory operation, reliability and fatigue resistance in a simulated aircraft vibration environment. The qualification test process consists of up to 5 parts - performance, endurance, gunfire, minimum integrity, and environmental stress screening. Vibration regions are presented in Figures 1, 18, 19 and 36 and the frequency spectrum shape and amplitude shall be as specified in Figures 2 through 49 for the applicable vibration regions. The testing shall be conducted at room ambient conditions unless otherwise specified in the detailed Procurement Specification.

For equipment mounted directly to panels, doors or other structure exposed directly to the airstream, all random vibration PSD and overall Grms levels will increase by a factor of 1.65 and 1.29, respectively.

4.2.2.1 Sinusoidal Vibration Test Procedure. This section describes the procedures to be used for testing equipment with a sinusoidal vibration environment. The equipment shall be mounted to the shaker or test fixture as outlined in Section 4.2.1.1 which describes the test setup. Details of the various test phases are as follows and shall be performed for each of the three orthogonal axes.

4.2.2.1.1 Resonance Survey. A sinusoidal resonance survey of the equipment shall be made using a slow frequency sweep from 5 to 2000 Hz. at the lessor of 0.05 inch double amplitude displacement or $\pm$ 2g acceleration. The sweep rate shall be logarithmic with an elapsed time of about 10 minutes. The equipment shall be turned on and must operate satisfactorily before, during and after the test. Resonant points shall be noted and the modes of each described.

A resonant mode shall be considered to be any frequency dependent mechanical disturbance which can be detected with accelerometers, visually, aurally or by other means. A resonant mode exists at any frequency at which the ratio of specimen response level to input level is at a peak such that both an increase and a decrease in the excitation frequency will produce a decrease in the specimen response level. A resonance can be characterized as follows:

a. For nonisolated equipment: A gain of two or greater between the output and input shall generally constitute a resonance.

b. For isolated equipment: In the region of isolation, a fifty percent reduction on both sides of a peak shall generally constitute a resonance.

Structural resonances to be determined are associated with the equipment primary mounting structure, main chassis and major components. Care should be used to be sure the resonances found are of a significant nature and are not highly localized due to panel, bracket or other minor component resonances.

The nature of the resonance shall be determined with mode shapes and the identification of component resonances. For closed equipment, methods will have to be used to determine the response of the internal components. The access covers may be removed for cases where these covers do not contribute significantly to the structural integrity of the item. In other cases, covers will have to be made up containing openings or transparent windows.

4.2.2.1.2 Sinusoidal Vibration Performance Test. The sinusoidal performance test consists of two phases - frequency cycling and resonance dwells. These are described below. These tests may be waived if satisfactory performance can be demonstrated during the more severe endurance level tests. This is part 1 of the 5 part qualification test process.

a) Sinusoidal Cycling - Vibrate the equipment in the first orthogonal axis with the frequency varying at a logarithmic rate from 5 to 2000 Hz and back to 5 Hz in approximately 20 minutes at double amplitude and acceleration levels in accordance with the applicable performance test curve. The equipment specification shall identify the correct test curve. Resonances shall be noted during this test and compared with those found in the low level resonance survey. Resonances from both tests shall be considered when defining the resonant dwell frequencies. The total vibration cycling time shall be a function of the number of resonances per the Figure 8 test schedule. The equipment shall operate during this test and must demonstrate specified performance. At the conclusion of the test, the equipment shall be closely inspected for any failure. Repeat this test in the other two orthogonal axes.

b) Sinusoidal Dwells - Vibrate the equipment in the first orthogonal axis at the resonant points obtained by the resonance survey or noted during the vibration cycling test. Use double amplitude and acceleration levels in accordance with the performance test curve defined by the equipment specification. Vibration dwells shall be for 5 minutes duration at each resonant frequency. If more than four resonant frequencies are found, only the four most severe shall be used for resonant dwell tests per the test schedule of Figure 8. The resonant frequency must be adjusted at the beginning and throughout the dwell test to maintain the maximum response. Some shift in the resonant frequency due to amplitude nonlinearity and changes in the dynamic system should be expected. Large changes in the resonant frequency, however, may indicate a failure. The equipment shall operate during this test and must demonstrate specified performance. At the conclusion of the test, the equipment shall be closely inspected for any failure. Repeat this test in the other two orthogonal axes.

4.2.2.1.3 Sinusoidal Vibration Endurance Test. This is part 2 of the 5 part qualification test process. The sinusoidal endurance test, like the performance test, consists of two phases - frequency cycling and resonance dwells. The equipment shall be tested according to the same procedures as given for the performance test in Section 4.2.2.1.2 except that the endurance test levels and durations are applicable. The equipment shall operate during this test, but shall not be required to give specified performance. At the conclusion of this test, however, the specified performance must be satisfactorily demonstrated. The equipment shall be closely inspected for any failures following each test phase.

4.2.2.2 Random Vibration Test Procedure. This section describes the procedures to be used for testing equipment with a random vibration environment. The equipment shall be mounted to the shaker or test fixture as outlined in Section 4.2.1.1 which describes the test setup. Details of the various test phases are as follows and shall be performed for each of the three orthogonal axes.

4.2.2.2.1 Resonance Survey. A sinusoidal resonance survey shall be performed to identify equipment frequencies which exhibit resonances. Conduct the resonance survey test as described in Section 4.2.2.1.1.

4.2.2.2.2 Performance Test. This is part 1 of the 5 part qualification test process. The equipment shall be vibrated using the applicable performance level random vibration test curve for a duration of 30 minutes per axis. The equipment shall be operating and must demonstrate specified performance before, during and following the vibration test. At the conclusion of each test phase, the equipment shall be closely inspected for any failure. These tests may be waived if satisfactory performance can be demonstrated during the more severe endurance level tests.

4.2.2.2.3 Endurance Test. This is part 2 of the 5 part qualification test process. The equipment shall be tested according to the same procedures as given for the performance test in Section 4.2.2.2.2 except the endurance test levels and the 2.0 hour per axis duration shall be used. The equipment shall be operating during the test but need not show performance. Specified performance, however, must be demonstrated before and after these tests. At the conclusion of each test phase, the equipment shall be closely inspected for any failure.

4.2.2.2.4 Alternate Endurance Test. For some equipment, due to its weight and the high test levels, available shaker systems will not be able to input the required spectrum shape and test levels. The alternate procedure consists of two parts. The tests shall be performed in each of the three orthogonal axes.

The first part is a test where the frequency spectrum shape is per the applicable test curve and the power spectral density level is set below the required level, but as high as the shaker system capability. The equipment shall be tested for half the normal test time at this level. The equipment shall be operating during the test period but need not perform within specified tolerances. The equipment shall perform within specified tolerances after completion of the test.

The second part is to break the frequency spectrum into a number of narrow frequency bands. The width of these bands shall be such that the shaker system can input the specified power spectral density level over this band. The equipment shall be tested for half the normal test time for each band. The equipment shall be operating during the test but need not perform within specified tolerances. The equipment shall perform within specified tolerances after completion of the test. This procedure is repeated for the number of bands required to cover the total frequency range of the vibration spectrum.

4.2.2.2.5 Extended Performance Life Test. In some cases the equipment supplier may want to demonstrate a lifetime, or endurance capability without using the higher endurance test levels. In order to address this possibility, an extended performance level test can be substituted for the endurance test. Instead of the 2.0 hour per axis endurance level test a full lifetime two part performance levels test can be used as follows:

Part 1 - Conduct a test with the performance test curve using only the portion of the frequency spectrum above 100 Hz. The duration of this test shall be 54 hours per axis.

Part 2 - Conduct a test with the performance test curve using only the portion of the frequency spectrum below 100 Hz. The duration of this test is a function of the equipment location in the aircraft as follow:

Equipment Location	Test Duration (per axis)
Fuselage	15 Hours
CFT's	15
Wing	15
Vertical Tail	7
Horizontal Tail	25

The equipment shall be operating and must demonstrate specified performance before, during and following the vibration test. At the conclusion of each test phase, the equipment shall be closely inspected for any failure.

4.2.2.3 Gunfire Vibration Test Procedure. This is part 3 of the 5 part qualification test process. The following additional tests are required for equipment located in regions of the aircraft affected by gunfire. Regions so affected are defined in Figure 36. These tests consist of a sinusoidal vibration test in the frequency range of 50 to 300 Hz and a random test in the frequency range from 300 to 2000 Hz.

4.2.2.3.1 Gunfire Sinusoidal Vibration Test Procedure. The test procedures specified in paragraph 4.2.2.1 are applicable except as noted herein and in Figure 49. The sinusoidal vibration levels for the 50 to 300 Hz frequency range are defined in Figures 37 through 48 for the 20mm gunfire environment. A sinusoidal resonance survey of the equipment shall be made using a slow frequency sweep from 50 to 300 Hz at these levels. The sweep rate shall be logarithmic with an elapsed time of about five minutes. Resonances shall be used for vibration swept dwell tests. Cycling and dwell testing shall consist of logarithmic sweeps from 50 to 300 Hz in approximately five minutes plus swept dwell periods in accordance with Figure 49. The equipment shall be operating during the test period and must perform within specified tolerances unless otherwise stated by the Procurement Specification. The equipment shall perform within specified tolerances after completion of the test. The tests shall be performed in each of the three orthogonal axes.

4.2.2.3.2 Gunfire Random Vibration Test Procedure. The test procedures specified in paragraph 4.2.2.2 are applicable except as noted herein. The equipment shall be vibrated along the same orthogonal axis employed therein in accordance with the applicable 20mm gunfire random vibration spectrum shape and test level from Figures 38 through 48 for 10 minutes per axis. The equipment shall be operating during the test period and must perform within specified tolerances unless otherwise stated by the Procurement Specification. The equipment shall perform within specified tolerances after completion of the test. The tests shall be performed in each of the three orthogonal axes.

4.2.2.3.3 Gunfire Random Vibration Alternate Test Procedure. For some equipment, due to its weight and the high test levels, available shaker systems will not be able to input the required spectrum shape and test levels. The alternate procedure consists of two parts. The tests shall be performed in each of the three orthogonal axes.

The first part is a test where the frequency spectrum shape is per the applicable test curve and the power spectral density level is set below the required level, but as high as the shaker system capability. The equipment shall be tested for half the normal test time at this level. The equipment shall be operating during the test period and must perform within specified tolerances unless otherwise stated by the Procurement Specification. The equipment shall perform within specified tolerances after completion of the test.

The second part is to break the frequency spectrum into a number of narrow frequency bands. The width of these bands shall be such that the shaker system can input the specified power spectral density level over this band. The equipment shall be tested for half the normal test time for each band. The equipment shall be operating during the test period and must perform within specified tolerances unless otherwise stated by the Procurement Specification. The equipment shall perform within specified tolerances after completion of the test. This procedure is repeated for the number of bands required to cover the total frequency range of the vibration spectrum.

4.2.2.4 Vibration Isolated Equipment Test Procedure. Vibration testing of equipment mounted on vibration isolators may be conducted either with or without the isolators in place. If the vibration isolation system is supplied with the equipment, then the testing should be conducted with the equipment mounted on the isolators as described below. If the vibration isolators are provided by MCAIR as part of the equipment mounting in the aircraft, then testing may be conducted either on isolators or hard mounted as described below. The decision of which method to use is subject to MCAIR approval.

4.2.2.4.1 Testing On Vibration Isolators. The equipment shall be mounted to the shaker using the vibration isolation system. Perform the applicable sinusoidal or random test defined in either 4.2.2.1 or 4.2.2.2 above. Gunfire tests defined in 4.2.2.3 shall also be performed if required by the applicable procurement specification.

To prevent overheating of the vibration isolation system during sinusoidal dwell or random testing at the isolation system resonant frequency, testing may be conducted as a series of short duration tests such that the sum of these short tests equals the total required test time.

4.2.2.4.2 Testing With Vibration Isolators Removed. Vibration test levels must be defined to compensate for the removal of the isolation system. The applicable vibration test levels shall be adjusted using the vibration isolation transfer functions of Figure 56 (sinusoidal or random). If actual measured transfer function data for the specific equipment isolation system combination is available, it may be used in place of that provided herein.

The equipment shall be mounted to the shaker without the vibration isolation system. Perform the applicable sinusoidal or random test defined in either 4.2.2.1 or 4.2.2.2 above. Gunfire tests defined in 4.2.2.3 shall also be performed if required by the applicable procurement specification.

4.2.2.5 Minimum Integrity Test Procedure. This is part 4 of the 5 part qualification test process. Minimum integrity tests shall be applied as a supplemental test for:

a. Items tested on vibration isolators.

b. Items tested normally (hard) mounted to levels and durations less stringent than the applicable minimum integrity test requirements.

The equipment shall be rigidly attached to the vibration shaker in the first orthogonal axis. The equipment shall be turned on during this test but need only demonstrate specified performance before and after the vibration test in each axis. Testing shall be conducted at the level and duration defined by Figure 50. After completion of the first axis, carefully examine the equipment for any failures and demonstrate performance. Repeat the test on the other two orthogonal axes.

4.2.2.6 Environmental Stress Screening (ESS). This is part 5 of the 5 part qualification test process. Each pre-production and production equipment including units intended for shipment as spares shall be subjected to ESS testing prior to shipment from the seller. This requirement applies to electronic equipment only.

The stress screening test shall be used as both a supplemental test in the qualification test sequence and as a method to identify any latent defects or problem areas in each production unit prior to shipment to the customer. Testing shall be conducted at the random vibration level shown on Figure 51. When conducted as a supplement to the qualification process, all three axes shall be tested for 10 minutes each. When conducted as a reliability screening test on each production unit, only two axes need be tested as follows. Electronic equipment with the circuit boards in one plane shall be vibrated for 10 minutes in the direction perpendicular to the plane of the circuit boards and 10 minutes in one of the other two major axes. When the components in the unit are oriented in more than one plane, the unit shall be vibrated for 10 minutes in each of two orthogonal axes at the discretion of the seller, but with agreement from the buyer.

Testing shall be conducted with the unit rigidly attached to the vibration shaker. The unit shall be turned on and must demonstrate specified performance before, during and after the test. After testing is completed, carefully examine the unit for any sign of failure. Any failure during the qualification supplemental test shall require the same corrective action and retest as defined for the other portions of the qualification testing. Failures during the reliability screening test shall be repaired and retested without failure prior to shipment to the buyer. A record of vibration related failures during screening shall be maintained to identify possible design weaknesses.

In the event measured data are available for equipment response during this test, some flexibility can be used in tailoring the ESS requirements to compensate for resonances. Incorporation of this feature must be approved by and coordinated with the buyer's dynamicist.

4.2.2.7 Sinusoidal Vibration Qualification Test Procedure. The qualification test procedure for equipment with sinusoidal vibration requirements shall consist of up to five parts. The completion of all five of these parts is required to be considered qualified. The five parts are described in other sections of this report as follows:

Part 1 - Sinusoidal Performance Test: Sections 4.2.2.1, 4.2.2.1.1 and 4.2.2.1.2.
Part 2 - Sinusoidal Endurance Tests: Section 4.2.2.1.3
Part 3 - Gunfire Vibration Tests: Sections 4.2.2.3, 4.2.2.3.1 and 4.2.2.3.2. (If Applicable)
Part 4 - Minimum Integrity Tests: Section 4.2.2.5. (Not required if endurance test levels are higher than the minimum integrity levels at all frequencies.)
Part 5 - Environmental Stress Screening Tests: Section 4.2.2.6.

4.2.2.8 Random Vibration Qualification Test Procedure. The qualification test procedure for equipment with random vibration requirements shall consist of up to five parts. The completion of all five of these parts is required to be considered qualified. The five parts are described in other sections of this report as follows:

Part 1 - Random Performance Test: Sections 4.2.2.2, 4.2.2.2.1 and 4.2.2.2.2.
Part 2 - Random Endurance Tests: Section 4.2.2.2.3
Part 3 - Gunfire Vibration Tests: Sections 4.2.2.3, 4.2.2.3.1 and 4.2.2.3.2. (If Applicable)
Part 4 - Minimum Integrity Tests: Section 4.2.2.5. (Not required if endurance test levels are higher than the minimum integrity levels at all frequencies.)
Part 5 - Environmental Stress Screening Tests: Section 4.2.2.6.

4.2.2.9 Flightworthiness Test Procedure. Flightworthiness testing is conducted to demonstrate a minimum capability equivalent to about 50 flight hours. This test may be used for equipment to be flown in flight test programs or for delivery of production hardware prior to completion of qualification testing. Flightworthiness testing shall be conducted according to the performance vibration test procedures as given in Section 4.2.2.2.2. The equipment specifications shall specify the applicable test curves. The crash safety shock test shall also be performed if the equipment is to be mounted in the cockpit. Gunfire testing is not required unless specifically defined in the equipment specification document.

4.2.3 Reliability Development Test Requirements. Vibration tests are required to demonstrate satisfactory equipment reliability in an operational environment. Reliability development tests shall be performed as defined by the specification document for the equipment.

These tests shall be performed on preproduction equipment. The tests are structured to identify high risk failure items which would cause the equipment to exhibit an unacceptable level of reliability during operational usage. The RDT shall be conducted for a sum total of 4000 'on' hours divided between two test articles. Neither of the test articles shall accumulate more than 2400 hours of the total.

Test article orientation shall be in the axis normal to a majority of printed circuit boards. The equipment shall be mounted on the vibration table to simulate the service installation orientation including all vibration mounts and other holding devices plus all electrical cables and other connections necessary for proper operation. Vibration transducers shall be used to monitor both vibration input and response of the equipment. Tests shall be conducted as follows.

This test is designed to accumulate an entire fatigue lifetime on one of the test articles and half a fatigue lifetime on the other test article. One test specimen shall be subjected to a one-half vibration lifetime at the beginning of the test. This shall be accomplished by exposing the specimen to 6.4 hrs of nongunfire vibration at 100% performance level ($f \leq 100$ Hz) and 21 hrs at 100% performance level ($f \geq 100$ Hz) per axis. This specimen shall also be exposed to gunfire vibration for half of the times presented in Figure 49 ($50<f<300$ Hz) and 5 minutes of gunfire random vibration ($f \geq 300$ Hz). Following this, vibration shall be applied continuously to each test article during the equipment 'on' portion of the test cycle in accordance with MIL-STD-781C. This portion of the test will expose both test articles to a one-half vibration lifetime each. Unless defined by the specification document, the random vibration test levels shall be based on those defined herein for the appropriate vibration region. The test cycle shall use vibration levels and durations as shown on Figure 52.

As an alternative, random vibration may be conducted with the test article removed from the test chamber. This test is designed to accumulate one fatigue lifetime on one test article and half a fatigue lifetime on the other test article. In this event, one test specimen shall be subjected to a one-half vibration lifetime (one hour of endurance level testing per axis) at the beginning of the test. This unit shall be subjected to the approved performance tests prior to initiation of temperature cycling. Both test articles shall then be tested in accordance with the MIL-STD-781C thermal test cycle. The test articles shall each be subjected to one hour of endurance level random vibration per axis divided into 4 periods of 15 minutes each spaced equally throughout the scheduled test time. Test time accumulated during the vibration periods is considered valid 'on' time. Performance demonstration is not required during the vibration periods but must be shown before and after.

Any vibration related failure shall require trouble shooting and corrective action. A problem/failure report shall be prepared for each failure. The RDT shall not be considered complete until corrective action for all vibration failures has been resolved to the satisfaction of MCAIR and USAF.

4.2.4 Pods and Weapons. Vibration test requirements for externally carried pods and weapons are shown on Figures 18 through 35. Requirements for aircraft pylon and store stations are interface environments between the aircraft and the pod or weapon. Requirements for the various pods and weapons are based on actual measurements for carriage of those items on F-15 aircraft.

Vibration testing of 'all up round' pods and weapons present some difficult challenges. Due to the multi-source excitation from the aircraft structure and aerodynamics, single or multiple shakers are hard pressed to duplicate the actual vibration response during carriage on the aircraft.

The recommended test procedure for pods and weapons is to divide the testing into two parts for buffet and non-buffet vibration environments. This process assumes the low frequency buffet vibration is generated by the aircraft and is transmitted to the pods or weapon through their attachment to the aircraft. The high frequency non-buffet vibration is assumed to be generated by the aerodynamic flow passing over the pod or weapon and is transmitted to the store over it's entire length.

Part 1 of the test procedure will expose the store to buffet vibration levels. These levels are defined as the applicable vibration curve between 5 and 100 Hz. For this part, the store should be attached to the normal mounting hardware (launcher, adapter, pylon, etc.) and rigidly mounted on the vibration shaker in the first axis. The store shall be vibrated using the appropriate test level and duration defined in the contractual document. The unit shall be checked for failures following each test phase. Repeat this to include all three axes.

Part 2 of the test procedure will expose the store to non - buffet vibration levels. These levels are defined as the applicable vibration curve between 100 and 2000 Hz. For this part, the store should be hung with a soft suspension system (bungie cords, etc.) and the vibration shaker attached to the store with a drive link in the first axis. The store shall be vibrated using the appropriate test level and duration defined in the contractual document. The unit shall be checked for failures following each test phase. Repeat this to include all three axes.

4.3 Acoustic Noise Susceptibility Test Requirements. Acoustic noise zones for the aircraft under non-gunfire and gunfire environments are shown on Figures 58 and 60 respectively. This test shall demonstrate that the equipment will not incur performance degradation and/or physical damage when exposed to a wide band acoustic noise environment of the overall noise level and relative power distribution as shown in Figures 59 and 61. Equipment located in areas where the nominal overall performance noise level is 140 dB (re 0.0002 microbar) or less need not be tested to the acoustic noise environment. However, resistance to acoustic noise shall remain as a design requirement. For equipment in the aircraft zones affected by gunfire, the basic non - gunfire acoustic noise test is supplemented by the additional gunfire acoustic noise test. The equipment must demonstrate specified performance during gunfire unless stated otherwise by the Procurement Specification.

4.3.1 Acoustic Test - General. The general acoustic test requirements for sequence of tests, performance record, success criteria, failure criteria, and corrective action/retest shall be as defined in sections 4.2.1.2, 4.2.1.3, 4.2.1.8, 4.2.1.9, and 4.2.1.10 respectively. The testing shall be conducted at room ambient conditions unless otherwise specified in the detailed Procurement Specification.

4.3.2 Test Chamber. A reverberation type test chamber, suitably formed and proportioned to produce a diffuse sound field, is required. The sound energy density should be very nearly uniform throughout the enclosure. A pentagonal chamber configuration is recommended. Acute angles of adjacent chamber walls shall be avoided where ever possible.

4.3.3 Test Setup. The test item shall be suspended in the test chamber by means of soft suspension springs or elastic cords. The natural frequency of all modes of suspension shall be less than 25 Hz. The test item shall be exposed on every surface to the sound field when centrally located in the test chamber. The test item volume should be no more than 10 percent of the test chamber volume. If the test chamber is a rectanguloid, no major surface of the test item shall be installed parallel to the chamber wall.

4.3.4 Performance Acoustic Noise Test Procedure. The specified performance sound pressure field shall be measured without the test item mounted in the test chamber. Measurements shall be made using a microphone to define the sound field within the central 10% of the test chamber volume. The specified performance overall sound pressure level from Figure 59 shall be introduced into the chamber and adjusted to conform with the octave band frequency spectrum specified for the applicable acoustic noise zone. The average sound pressure distribution (overall level) should be uniform within -0 to +4 dB of the desired value. The test item shall be placed in the chamber as specified in Section 4.3.3. At least three microphones shall be monitored. They shall be located in proximity to each major dissimilar test item surface, at least 18 inches from the test item surface or one half of the distance to the nearest chamber wall, whichever is less. The average overall sound pressure distribution around the test item should be uniform within -0 to +4 dB of the desired value. The test item shall be operating during this test and shall give specified performance both during and after the 30 minute test. The requirements for this performance test may be waived if test item performance requirements can be met during the more stringent endurance level testing.

4.3.5 Endurance Acoustic Noise Test Procedure. The test item shall be tested according to the same procedure as given for the performance test in Section 4.3.4 except that the acoustic noise endurance test levels and spectrum of Figure 59 are applicable. The test item shall be operating during this test, but shall not be required to give specified performance. The test shall be for 2.0 hours and at the conclusion of this test, the specified performance shall be satisfactorily demonstrated, and the test item shall be closely inspected for any failure.

4.3.6 Gunfire Acoustic Noise Test Procedure. The following additional test is applicable for equipment located in zones of the aircraft affected by gunfire. Zones so affected are defined on Figure 60. The test item shall be tested according to the same procedure as given for the performance test in Section 4.3.4 except the specified gunfire overall sound pressure level, octave band spectrum, and test time of Figure 61 are applicable. The test item shall be operating during this test and must demonstrate specified performance unless the Procurement Specification indicates that this is not required.

4.3.7 Alternate Acoustic Noise Test Procedure. For some equipment, available acoustic test systems will not be able to input the required test levels. The alternate procedure consists of two parts. The first is a test where the spectrum shape is per the applicable figure (Figure 59 or 61) but the overall sound pressure level is set as high as the acoustic system capability. The equipment shall be tested for half the normal test time at this level. The equipment shall be operating during the test period and must perform within specified tolerances unless otherwise stated by the Procurement Specification. The equipment shall perform within specified tolerances after completion of the test.

The second part is to break the frequency spectrum into a number of narrow frequency bands. The width of these bands shall be such that the acoustic system can input the specified sound pressure level over this band. The equipment shall be tested for half the normal test time for each band. In the event that the specified sound pressure levels are still not attainable, the highest level available in each one third octave frequency band shall be used. The equipment shall be operating during the test period and must perform within specified tolerances unless otherwise stated by the Procurement Specification. The equipment shall perform within specified tolerances after completion of the test. This procedure is repeated for the number of bands required to cover the total frequency range of the acoustic spectrum.

4.3.8 Pods and Weapons. Stores shall be acoustically tested in the same manner as other aircraft equipment. The procedures outlined in Sections 4.3, 4.3.1, 4.3.2, 4.3.3, 4.3.4, 4.3.5 and 4.3.7 shall be utilized.

4.4 Shock Test Requirements. The structural integrity and functional adequacy of the equipment under the conditions of service use shall be determined by the service shock test. The structural adequacy of the equipment mounting, mounting base and other holding devices to withstand a crash situation shall be determined by the crash safety shock test. The ability to survive and function normally after being dropped shall be demonstrated by the transit drop shock test.

This test procedure will not be required along any axis for which a sufficiently severe random vibration test procedure is required, provided that the equipment operational requirements are comparable. The process described in MIL-STD-810E, Method 516.4, Procedure I - Functional Shock, may be used to determine the comparison between the applicable random vibration levels and the shock requirements. Use of this shock test exemption must be approved by the buyer's dynamicist.

4.4.1 Shock Test - General. The general shock test requirements for sequence of tests, performance record, test axes, success criteria, failure criteria, and corrective action/retest shall be as defined in sections 4.2.1.2, 4.2.1.3, 4.2.1.6, 4.2.1.8, 4.2.1.9, and 4.2.1.10 respectively. Shock regions are presented in Figure 63 and the shock pulse shape, amplitude, and time duration shall be as specified in Figure 64 for the applicable shock regions. The testing shall be conducted at room ambient conditions unless otherwise specified in the detailed Procurement Specification.

4.4.2 Shock Test Setup. The test item shall be rigidly attached to the shock machine or an intermediate structure which is so designed as to be capable of transmitting the specified shock to the test item attachment points. The input control sensors shall be located as near as possible to the test item attach points. The test item shall be attached to the test fixture by the mounting means used in the service installation, including vibration isolators and other holding devices plus all electrical cables and any other connections necessary for proper operation. Whenever possible, the test load shall be distributed uniformly on the test platform in order to minimize the affects of unbalanced loads.

4.4.3 Service Shock Test. The equipment shall be operating during the impacts and critical performance parameters monitored unless specifically not required by the Procurement Specification. The test item shall be subjected to a total of 18 impacts. The impact shocks shall be applied in the following directions:

a. First orthogonal axis - three in each direction
b. Second orthogonal axis - three in each direction
c. Third orthogonal axis - three in each direction

After each shock, the test item shall be closely inspected for any evidence of mechanical failure, and at the conclusion of testing in each axis, a performance check shall be made.

If the equipment is installed on a vibration isolated shelf or panel, an alternate shock test may be used with the Buyer's concurrence. The equipment shall be removed from the isolated shelf and rigidly attached to the shock test machine and subjected to shock impacts as described above. Applicable shock levels and durations of Figure 64 shall be used. This procedure is a candidate for use when it is not possible or practical to test the entire isolated assembly. It does not apply to individually isolated units.

4.4.4 Crash Safety Shock Test (Equipment Normally Mounted). The equipment or a dummy load (permissible for electronic equipment only) shall be attached to the test fixture by the mounting means intended for use in the service installation including vibration isolators and other holding devices. If a dummy load is used, it shall simulate equipment weight, c.g. location, approximate radii of gyration and attach point structure. Testing shall be according to the procedures in Section 4.4.3 using the applicable test levels of Figure 64. The number of shocks in each direction shall be two in lieu of three. The equipment attachments, mounting base, and vibration isolators (if applicable) shall be examined for structural failure. Bending and distortion are permitted, but there shall be no structural failure of the attach points and the equipment or dummy load shall remain in place.

If the equipment is installed on a vibration isolated shelf or panel, an alternate shock test may be used with the Buyer's concurrence. The equipment shall be removed from the isolated shelf and rigidly attached to the shock test machine and subjected to shock impacts as described above. Applicable shock levels and durations of Figure 64 shall be used. This procedure is a candidate for use when it is not possible or practical to test the entire isolated assembly. It does not apply to individually isolated units.

4.4.5 Transit Drop Shock Test. This procedure is intended for equipment in its transit or carrying case such as data storage devices, cryptographic devices or other items carried to the aircraft by the aircrew. It is used to determine if the item is capable of withstanding the shocks normally induced by loading, unloading and dropping the equipment. This is not intended for shocks encountered in a normal logistic shipping environment as experienced by shipping containers. Levels for this test were set by considering how hand carried equipment might commonly be dropped. Field data have shown that a typical piece of man-portable equipment will be dropped from heights up to 48 inches an average of five times during its life cycle.

The unit shall be dropped a total of five times from a height of 48 inches onto a concrete surface using a quick-release hook or drop tester machine. The five drops shall be conducted such that the unit falls on different sides or corners each time as follows:

Drop Number	Drop Orientation
1	on unit end
2	on unit side
3	on unit bottom
4	on unit corner
5	on unit corner opposite drop 4

The unit shall demonstrate specified performance before and after the drop tests. Some permanent deformation or abrasion is permissible, however, the unit must still perform its normal function such as slide into another unit, if applicable. Failure to meet these objectives shall require corrective action including redesign if necessary.

4.5 Acoustic Noise Generation Test Requirements. Noise measurement tests shall be conducted to demonstrate that acoustic noise generated by the equipment and airflow exits does not exceed the limits specified by Section 3.4 of this document. Acoustic noise measurements shall be obtained for all operating modes of the equipment. The measurements described below shall be made across each face of the equipment.

A microphone shall be located 2 feet from and directed toward and perpendicular to the equipment face. There shall be no obstructions or objects placed between the microphone and the equipment. Noise measurements shall be taken for each operating mode. The overall sound pressure level and the octave band sound pressure levels shall be measured and recorded for each operating mode of the equipment. The noise levels shall be recorded in decibels relative to 0.0002 microbar and the overall and octave band noise levels shall not exceed those specified in Figure 62.

4.6 Flow Resonance Test Requirements. This test shall demonstrate that the equipment will not incur physical damage or performance degradation when exposed to the most severe flow resonance condition. The required test consists of determining the most severe resonance condition and then dwelling at this condition for 50 hours.

The equipment shall be subjected to flow tests to determine if the equipment has critical resonant frequencies when subjected to the complete range of required operating flows, pressures and temperatures. The method of determining critical resonant frequencies shall be by monitoring the vibration or auditory response.

The equipment shall be subjected to a 50 hour dwell test at the fluid flow condition which causes the most severe resonance. If there are no resonances, dwell for 50 hours at the maximum flow rate. The equipment shall show no evidence of structural damage or leakage after the 50 hour test period.

4.7 Acceleration Loads Test Procedure. Acceleration tests are required to demonstrate that the equipment can structurally withstand the forces that are expected to be induced by acceleration in the service environment and function without degradation during and following exposure to these forces. Acceleration tests should be applied to all equipment which is susceptible to acceleration loads as specified by the equipment Procurement Specification. The intent of the test is to determine whether or not the accelerations cause permanent deformations and fractures that disable or destroy the equipment, relays to open or close, instruments to deflect from their readings, electrical connectors to develop discontinuities, electronic circuit boards to short out or open up, motors to stall due to increased mechanical loads, equipment to malfunction due to interference of moving parts, seals to leak, and so forth.

4.7.1 Acceleration Test - General. The general acceleration test requirements for performance record, test axes, success criteria, failure criteria, and corrective action/retest shall be as defined in sections 4.2.1.3, 4.2.1.6, 4.2.1.8, 4.2.1.9, and 4.2.1.10 respectively. Normal operating and limit acceleration loads trends with equipment location are shown in Figures 66 through 71. Actual test levels and conditions must be determined on an individual basis for specific equipment items.

4.7.2 Acceleration Test Setup. Either of two facilities may be used for the acceleration tests: a centrifuge, or a track and rocket sled facility. A centrifuge of adequate size is recommended for all structural and most operational tests because of the convenience and ease of control. However, the performance of space oriented equipment, such as gyros, space control platforms, etc., are difficult to test on a centrifuge, even when a counter rotating fixture is employed. A rocket sled run is advantageous where strictly linear acceleration is required.

4.7.2.1 Centrifuge Mounting. When a centrifuge is used to attain the required acceleration levels, the test item shall be oriented to obtain the vectorial acceleration for the specified loading condition. After the test item is properly oriented and mounted on the centrifuge, measurements and calculations must be made to assure that the end of the test item nearest to the center of the centrifuge will be subjected to no less than 90% of the acceleration level specified for the test. If the acceleration level of the nearest point is found to be less than 90% of the specified level, the test item must be mounted further out on the centrifuge arm and the rotational speed adjusted accordingly or a larger centrifuge used so the the end of the test item nearest to the center of the centrifuge is subjected to at least 90% of the specified level.

The furthest end of the test item should not be subjected to more than 110% of the level at the geometric center. If this results in a load factor at the nearest end of the test item to fall below 90% of the specified level, then this is considered an acceptable test compromise. For large test specimens, exceptions should be made for load gradients based on the existing availability of large centrifuges in commercial or government test facilities.

4.7.2.2 Rocket-Powered Sled Mounting. For tests utilizing a rocket-powered sled, the test item shall be mounted on the sled platform to obtain the vectorial acceleration for the specified loading condition. The test fixture should be designed to isolate sled vibrations from the test item. Since the sled and test item experience the same acceleration levels, only the orientation on the sled is critical.

4.7.3 Centrifuge Functional Test Procedure. This procedure shall be used to satisfy both the normal operating and limit loads test requirements. Install the test item on the centrifuge in accordance with Section 4.7.2.1 by its normal mounting means. Turn on the test item and place it in its operational mode. With the test item operating, bring the centrifuge up to the speed required to induce the specified limit load factor in the test item for the particular orientation as defined from Sections 3.6.1 and 3.6.2. Maintain this acceleration level after the centrifuge rpm has been stabilized for one minute, or the time required to demonstrate equipment performance, which ever is greater. Check the functional performance of the test item before, during and after the test and record the results. Repeat this test procedure for the remaining load conditions. The test item performance shall be within specifications as defined in the Procurement Specification and Sections 3.6.1 and 3.6.2 herein. There shall be no mechanical failures or malfunctions due to the applied acceleration.

4.7.4 Centrifuge Structural Test Procedure. This procedure shall be used to satisfy the ultimate loads test requirements. The test item shall be installed on the centrifuge in accordance with section 4.7.2.1 by its normal mounting means. The centrifuge shall be brought up to the rotational speed required to produce the ultimate radial acceleration required in the applicable equipment specification and Section 3.6.3. This acceleration shall be stabilized and maintained for a period of not less than one minute. Repeat this test procedure for the remaining load conditions. Equipment will not be required to function after being subjected to the ultimate loading conditions. Bending and distortion of the equipment is permitted, however, there shall be no structural failure which causes the equipment to come loose from its mounts.

4.7.5 Rocket Sled Functional Test Procedure. This procedure shall be used for normal operating and limit loading conditions. Install the test item on the rocket powered sled in accordance with Section 4.7.2.2 by its normal mounting means. Turn on the test item and place it in its operational mode. With the test item operating, accelerate the sled to the level required to induce the specified limit load factor in the test item for the particular orientation. Check the functional performance of the test item before, during and after the test and record the results. Due to limitations of track and sled facilities, additional test runs may be required to adequately demonstrate acceptable performance of the test item while under the test loading. Repeat this test procedure for the remaining load conditions. The test item performance shall be within specifications as defined in the Procurement Specification and Sections 3.6.1 and 3.6.2. There shall be no mechanical failures or malfunctions due to the applied acceleration.

4.7.6. Rocket Sled Structural Test Procedure. This procedure shall be used for ultimate loading conditions. The test item shall be installed on the rocket powered sled in accordance with Section 4.7.2.2 by its normal mounting means. Accelerate the sled to the level required to produce the ultimate acceleration required in the applicable equipment specification and Section 3.6.3. This acceleration shall be stabilized and maintained for a period of time consistent with track and sled facility limitations. Repeat this test procedure for the remaining load conditions. There shall be no mechanical failures or malfunctions due to the applied acceleration. Equipment will not be required to function after being subjected to the ultimate loading conditions. Bending and distortion of the equipment is permitted, however, there shall be no structural failure which causes the equipment to come loose from its mounts.

5. DOCUMENTATION:

Data required to be prepared and delivered by the Seller is specified in the Seller Data Requirements List (SDRL). This documentation shall be sufficient to verify that the equipment complies with the vibration, shock, acoustic and acceleration requirements of the Procurement Specification and this document. The information provided shall include, but not be limited to the following.

5.1 Qualification Test Procedure. This report shall be the equipment Seller's interpretation of the requirements of this document and the applicable Procurement Specification. It shall include a detail description of the test procedure that the Seller will use for qualification testing and indicate the sequence of tests. The following items shall be included.

5.1.1 Vibration Test Procedure. This section shall describe the test procedure to be followed by the Seller during vibration qualification tests and shall include the following:

a. Test Fixture. This shall include a detailed description of the test fixture. A drawing showing the item to be tested mounted in the fixture shall be provided. All wire bundles, hydraulic lines, etc. shall be shown. It shall address how the fixture dynamically simulates the actual aircraft mounting installation and that there are no significant structural resonances in the range of vibration test frequencies.

b. Axes Designation. This shall specify the location and orientation of the three orthogonal test axes.

c. Vibration Monitoring Instrumentation. The type and location of the instrumentation proposed to measure the input and response vibration of the equipment during testing shall be specified. Drawings shall be used to help identify these locations. The use of multiple input control averaging shall be discussed if applicable. Sufficient instrumentation shall be used to define the input level on the fixture at the equipment mounting locations and the response level on the equipment, both external and internal, at locations of interest which have resonances and/or significant response.

d. Equipment List. A list of equipment and instrumentation to be used during testing shall be provided. This list shall contain such items as the function of each item, the manufacturer's model number and the range and accuracy.

e. Determination Of Resonances. A description of the methods that will be used to determine the presence of a resonance shall be provided. Some of these methods are visual inspection (using a strobe light), Audio inspection (sharp changes in sound level), and by the normal vibration instrumentation (accelerometers, velocity pickups and strain gages). A resonance is defined in Section 4.2.2.1.1.

f. Vibration Spectra. A description of the vibration spectra which will be used in the testing shall be provided. A plot or graph showing vibration level versus frequency is recommended.

g. Test Time. The test times and test schedule for each portion of the vibration test shall be included.

h. Special Environments. A description of the methods that will be used to simulate other than room ambient environments, if required, during the qualification testing shall be included.

i. Specified Performance. The method of determining the performance of the equipment during vibration testing shall be included.

j. Other Data. Any other data required by the Procurement Specification or deemed by the Seller to be necessary and useful to define or clarify the vibration qualification test shall also be included.

5.1.2 Acoustic Noise Susceptibility Test Procedures. This section describes the test procedures to be followed by the Seller during acoustic noise susceptibility qualification tests and shall include the following:

a. Test Chamber. A detailed description of the test chamber and the noise generation equipment shall be provided.

b. Setup and Instrumentation. A description of the test setup and the type, location, and orientation of instrumentation used to monitor the noise input shall be provided. A sketch is required to show this.

c. Equipment List. A list of equipment and instrumentation to be utilized during testing shall be provided. This list shall contain such items as the generic function of each item, the manufacturer's model number, and the accuracy and range.

d. Test Spectra And Time. A description of the overall noise level and frequency distribution by octave bands to be utilized during the qualification testing shall be provided. A graph showing the noise level versus frequency in octave bands is required. The test time to be used shall also be included.

e. Specified Performance. The method of determining specified performance during acoustic tests shall be included.

f. Other Data. Any other data required by the Procurement Specification or deemed by the Seller to be necessary or useful to define or clarify the acoustic susceptibility qualification test shall also be included.

5.1.3 Shock Test Procedures. This section shall describe the test procedure to be followed by the Seller during shock qualification tests and shall include the following:

a. Test Fixture. A detailed description of the test fixture shall be provided. A drawing of the fixture is required.

b. Designation Of Axes. The location and orientation of the three orthogonal axes shall be specified.

c. Shock Instrumentation. The type and location of instrumentation used to measure the shock pulses shall be provided using sketches as required.

d. Equipment List. A list of equipment and instrumentation to be utilized during testing shall be provided. This list shall contain such items as the generic function of each item, the manufacturer's model number, and the accuracy and range.

e. Shock Duration And Intensity. A description of the time duration, shape, and peak value of the applied shock impulse shall be provided.

f. Test Setup. A general description of the shock test setup and associated equipment shall be provided.

g. Specified Performance. The method of determining the performance during shock tests shall be included.

h. Other Data. Any other data required by the Procurement Specification or deemed by the Seller to be necessary or useful to define or clarify the shock qualification test shall also be included.

5.1.4 Acoustic Noise Generation Test Procedures. This section shall describe the test procedures to be followed by the Seller during acoustic noise generation tests and shall include the following:

a. Setup and Instrumentation. A description of the test setup and the type, location, and orientation of instrumentation used for the noise measurements shall be provided.

b. Equipment List. A list of equipment and instrumentation to be utilized during the testing shall be provided. This list shall contain such items as the function of each item, the manufacturer's model number, and the accuracy and range of each piece of equipment.

c. Operating Modes. The operating modes of the equipment for which noise measurements are to be obtained must be provided.

d. Test Spectra. The overall noise level and frequency spectra to which the equipment is to show compliance shall be included.

e. Other Data. Any other data required by the Procurement Specification or deemed by the Seller to be necessary or useful to define or clarify the acoustic noise generation test shall also be included.

5.1.5 Flow Resonance Test Procedure. This shall describe the Seller's flow resonance test procedure.

a. Test Setup. This shall describe the test setup including the type and location of the instrumentation.

b. Test Description. This shall describe the tests performed to determine the most severe flow conditions.

c. Determination of Resonances. This shall describe the method used to analyze the data to determine the presence of the most severe resonance condition.

d. Leakage Check. This shall describe the method used to determine that the equipment showed no evidence of structural damage and successfully pass a leakage test after the 50 hour test period.

5.1.6 Acceleration Loads Test Procedure. This section shall describe the test procedures to be followed by the Seller during the acceleration loads tests and shall include the following:

a. Test Fixture. A detailed description of the test fixture to be used in the acceleration loads tests shall be provided.

b. Designation of Axes. The location and orientation of the three orthogonal axes shall be specified.

c. Acceleration Monitoring Instrumentation. The type and location of the instrumentation proposed to measure the acceleration shall be specified.

d. Equipment List. A list of equipment and instrumentation to be used during the testing shall be provided. This list shall include the function of each item, the manufacturer's model number, and the range and accuracy.

e. Test Levels. A description of the acceleration load factors to be used in the test shall be provided for each axis.

f. Specified Performance. The method of determining the performance during acceleration loads testing shall be included.

5.2 Qualification Test Report. This report shall document the results from the qualification test program. It shall include the following items:

a. Introduction. This section shall give general information of the type of equipment and the purpose and scope of the test program.

b. Description of the Test Item. This section shall give information necessary to identify the equipment being tested. Photographs of the equipment shall be included.

c. Test Program Chronological Log. This shall be kept for the complete test program, including retest, if any. The purpose of this log is to form a compact summary of the test program. This log shall be composed of the vibration, shock acoustic and acceleration test chronological logs as described in each of these test sections.

d. Failures During the Test Program. This section shall include photographs of any failures that occurred during the test programs. A detail explanation of the failure and the fix or fixes shall be included. A discussion of the failures during the retest portion of the test programs shall be included.

5.2.1 Vibration Tests. This section shall document the vibration qualification tests and shall include the following:

a. Vibration Test Setup. A description of the vibration test setup shall be presented to include:

1. A list of equipment and instrumentation utilized during the vibration tests shall be provided. This list shall contain, as a minimum for each equipment item, the name and function, the manufacturer's model number, the date of calibration and the range and accuracy.

2. A description of the test fixture showing how the test specimen is attached is required. The location of both input control and response accelerometers shall be described. Photographs and/or accurate sketches showing this information shall be provided for each of the three orthogonal test axes.

b. Vibration Test Procedure. A general discussion of the test procedure shall be presented. This discussion shall include, but not be limited to the sequence of tests, the vibration test spectra and test times in each axis, the methods used to determine resonances, and the procedure for determining equipment performance.

c. Vibration Test Results. The vibration test data and a discussion of the results shall be presented and must include the following:

1. Supporting Data. The test data may be included in appendices; however, where applicable, representative samples shall be included in the text as needed. The supporting data shall include:

Input - Plots of the actual vibration input control spectra for each axis and test level. If input averaging is used, both the average input and the individual input spectra shall be provided.

Resonance - Frequency response plots of transmissibility (response divided by input) versus frequency from the resonance survey test shall be provided for the equipment response locations. Frequencies selected for resonant dwell tests shall be identified on these plots. Response plots from either the sinusoidal or random tests (which ever is applicable) shall also be provided for both performance and endurance test levels.

Mode Shapes - Descriptions of resonant mode shapes shall be provided. Vector plots or other clear means of identifying the modes of vibration at significant resonances shall be presented.

Performance Records - The recorded performance of the equipment during and after the test shall be provided.

Mechanical Inspections - Data from inspections throughout and following the tests shall be included.

2. Chronological Test Log. A chronological log of the testing shall be presented. This log shall contain clear identification of the testing being performed (i.e. minimum integrity, random, sinusoidal, normally mounted, gunfire, etc.), the axis of excitation, the input vibration level and spectrum (i.e. sinusoidal performance, random endurance, etc. with reference to applicable curves), the test step (i.e. sweep cycling, resonance dwells, random vibration, resonance survey, etc.), the test frequency (i.e. the sweep range, the random range, dwell frequency, etc.), and the test time at each condition. Any test point where the equipment performance is not per the requirements of the Procurement Specification shall be noted in this log. A remarks section shall also be included as part of this log for inclusion of other pertinent information such as test environments that are different from room ambient, chronological identification and description of failures and corrective fixes, identification of resonant points, and the identification of retest parts of the program, if required.

3. Failures. Any failures and/or performance degradations during the vibration testing shall be fully discussed as well as the remedial action taken.

c. Vibration Test Conclusions. Conclusions and recommendations which support the results from the vibration tests shall be presented.

5.2.2 Shock Tests. This section shall document the shock qualification tests and shall include the following:

a. Shock Test Setup. A general description of the shock test setup shall be presented. A list of the instrumentation and equipment used during the tests shall be presented. This list shall contain, as a minimum for each item, the name and generic function, the manufacturer's model number and serial number, the date of calibration and the range and accuracy. Photographs of the test fixture and test item shall be included for each orthogonal axis. The location of input and response accelerometers shall also be shown in the photos.

b. Shock Test Procedure. A general discussion of the test procedures shall be presented. This discussion shall included the shock pulse level and duration, the number of pulses, the sequence of testing and methods of determining equipment performance.

c. Shock Test Results. The shock test results and a discussion of the results shall be presented. This shall include a full discussion of any failures and/or performance degradations that occur during the shock testing and the remedial action taken. Photographs or plots of the actual shock pulse wave shapes are required. This section shall also include a chronological log of the shock testing. This log shall indicate the type of test being performed (i.e. normally mounted, service or crash safety, etc.), the accumulated number of shock pulses applied, the orientation of the equipment, direction of shock, pulse amplitude and duration for each applied shock. Any point where the equipment performance is not per the requirements of the detail specification shall be noted in a remarks section, as well as the point of any failures. Nonstandard conditions should also be noted if the testing is conducted at other than room ambient conditions.

d. Shock Test Conclusions. The conclusions and recommendations of the shock tests shall be presented.

5.2.3 Acoustic Noise Susceptibility Tests. This section shall document the acoustic noise susceptibility qualification testing and shall include the following:

a. Description of Acoustic Noise Test Setup. This shall include a list of the instruments and equipment used during the qualification tests. This list shall contain as a minimum for each item, the generic function, the manufacturer's model and serial numbers, the date of calibration, and the range and accuracy. A description of the test chamber and suspension system for the test specimen, and photographs of the test setup shall be included.

b. Acoustic Noise Test Procedure. This shall include a general discussion of the test procedure and shall include plots of the required acoustic noise level.

c. Acoustic Noise Test Results. The test results and a discussion of them shall be presented. Any failures and/or performance degradations that occur during the test program and remedial action taken shall be fully discussed. Plots of the actual acoustic noise test levels and frequency spectra are required. A chronological log of the testing shall be included which indicates the type of testing (i.e. endurance, performance, gunfire, etc.), the accumulated test time, the noise intensity and frequency spectrum.

d. Acoustic Noise Test Conclusions. The conclusions and recommendations from the acoustic noise tests shall be presented.

5.2.4 Equipment Acoustic Noise Generation Tests. This section shall document the acoustic noise generation qualification testing and shall include the following:

a. Acoustic Noise Generation Test Setup. This shall include a list of the instruments and equipment utilized during the qualification tests. This list shall contain, as a minimum for each item, the generic function, the manufacturer's model number, the date of calibration, and the range and accuracy. A description of the test setup including photographs shall be provided.

b. Acoustic Noise Generation Test Procedures. This shall include a general discussion of the test procedure.

c. Acoustic Noise Generation Test Results. The test results and a discussion of the results shall be presented. Any failure that occurs and the remedial action taken shall be fully discussed. Plots of the actual overall and octave-band acoustic noise generated during the normal modes of equipment operation are required. A chronological log of the testing shall be included which indicates the face of the equipment, the frequency band being tested, and the intensity of the noise generated.

d. Acoustic Noise Generation Test Conclusions. The conclusions and recommendations from the acoustic noise generation tests shall be presented.

5.2.5 Flow Resonance Test. This section shall document the flow resonance testing and shall include the following:

a. Flow Resonance Test Setup. This shall include a list of instruments and equipment including their locations and tolerances. A description of the test setup shall be provided including photographs.

b. Flow Resonance Test Procedure. A general description of the test procedure shall be included.

c. Flow Resonance Test Results. Results from the flow resonance test, structural damage inspection and leakage test shall be included. Plots of acoustic level or other indicator versus fluid flow rate shall be included to show why the flow rate used for the dwell portion was selected.

d. Flow Resonance Test Conclusions. Conclusions and recommendations based on the test results shall be presented.

5.2.6 Acceleration Loads Test. This section shall document the acceleration loads testing and shall include the following:

a. Acceleration Loads Test Setup. A description of the acceleration loads test setup shall be presented including:

1. A list of the instruments and equipment used during the qualification tests is required. This list shall contain, as a minimum for each item, the generic function, the manufacturer's model and serial numbers, the date of calibration, and the range and accuracy.

2. A description of the test fixture showing how the test specimen is attached along with the location of monitoring accelerometers is required. Photographs and/or accurate sketches showing this information shall be provided for each of the orthogonal test axes.

b. Acceleration Loads Test Procedure. A general discussion of the test procedure shall be presented. This discussion shall include, but not be limited to, the sequence of tests, the acceleration load factors for each axis and the procedure for determining equipment performance.

c. Acceleration Test Results. The acceleration test results and a discussion of the results shall be presented. This shall include a full discussion of any failures and/or performance degradations that occur during the acceleration testing and the remedial action taken. This section shall include a chronological log of the acceleration testing. This log shall indicate the type of test being performed (i.e. limit, ultimate,etc.), the orientation of the equipment, and the acceleration load factor. Any point where the equipment performance is not per the requirements of the detail specification shall be noted in a remarks section, as well as the point of any failures. Nonstandard conditions should also be noted if the testing is conducted at other than room ambient conditions.

d. Acceleration Test Conclusions. The conclusions and recommendations of the acceleration loads test shall be presented.

5.3 Flightworthiness Test. Procedures and reports shall be the same as for the qualification tests.

6. REFERENCES:

1. MDC Report G397, "F-15 Vibration, Shock, and Acoustic Design Requirements and Test Procedures for Aircraft Equipment Installations", Rev C, 15 Dec 1969.

2. MDC Report A4246, "F-15 Vibration, Shock, and Acoustic Design Requirements and Test Procedures for Aircraft Equipment, Update Based on Ground and Flight Test Measure-ments", Rev B, 01 Nov 1985.

3. "F-15E/LANTIRN Environmental Design Criteria Report", CDRL Sequence No. 21032, Martin Marietta Corp., Jun 1987.

4. "Development of AMRAAM Vibration Requirements in ECP H-175, 2nd ed.", Task Order No. YM-921511, Sverdrup Technology Inc./TEAS Group, Eglin AFB, 03 Dec 1991.

5. "F-15E AMRAAM Vibration and Acoustic Environment Fuselage/Conformal Fuel Tank Captive Carriage, Vol. I: Flight Test Report", AMRAAM Program Office, ASD/YME, Eglin AFB, 18 Oct 1991.

6. "F-15E/T-20 AGM-65 Maverick Captive Flight Quick Look No. 2 Test Report", Air Force Task No. 16, P00120, Hughes Aircraft Company Missile Systems Group, 07 Mar 1988.

7. "GBU-15/BLU-109 Captive Carriage Test Vehicle Vibration Measurements", Report 87040, Teledyne Brown Engineering, 17 Aug 1990.

8. "Test Report for Early Vibration Fly Around of Captive Carriage SRAM T on F-15E Aircraft", Data Item DI-T-3718A/T, Sequence No. 1067, McDonnell Aircraft Company, 15 Aug 1990.

9. "Final Test Report, Air-Launched Antisatellite (ASAT) Captive Flight Tests #800-1 through -6 (CDRL 623A2), Vol. I", The Boeing Company, 21 Dec 1983.

Figure 1
Non-gunfire Vibration Regions

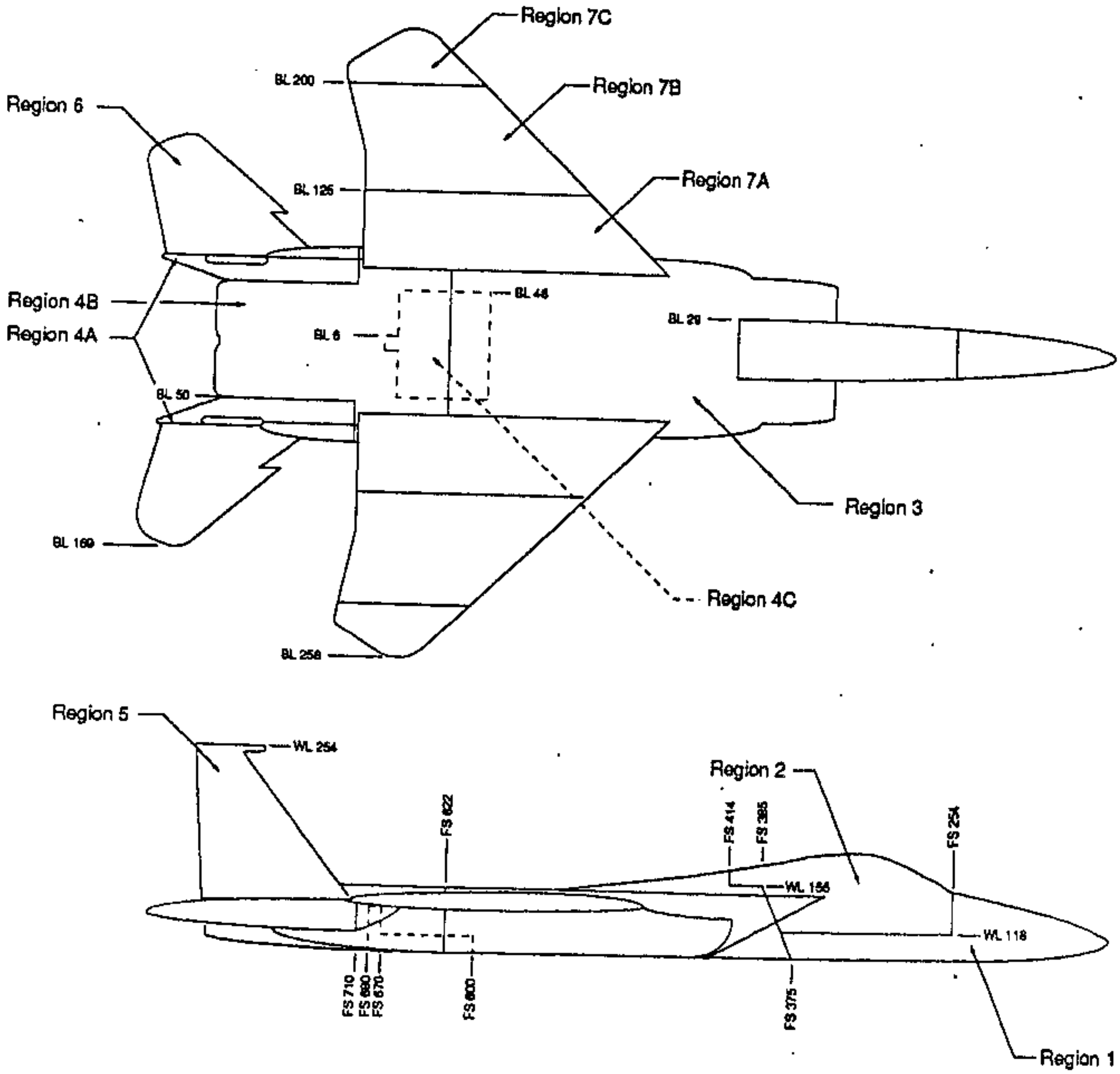
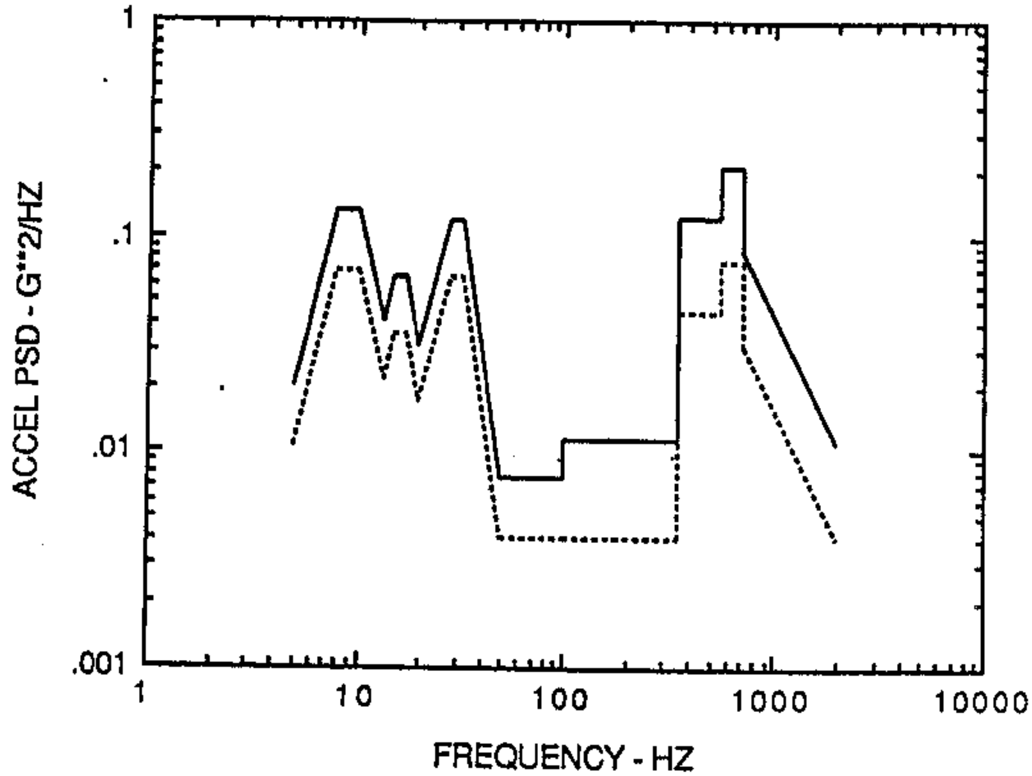


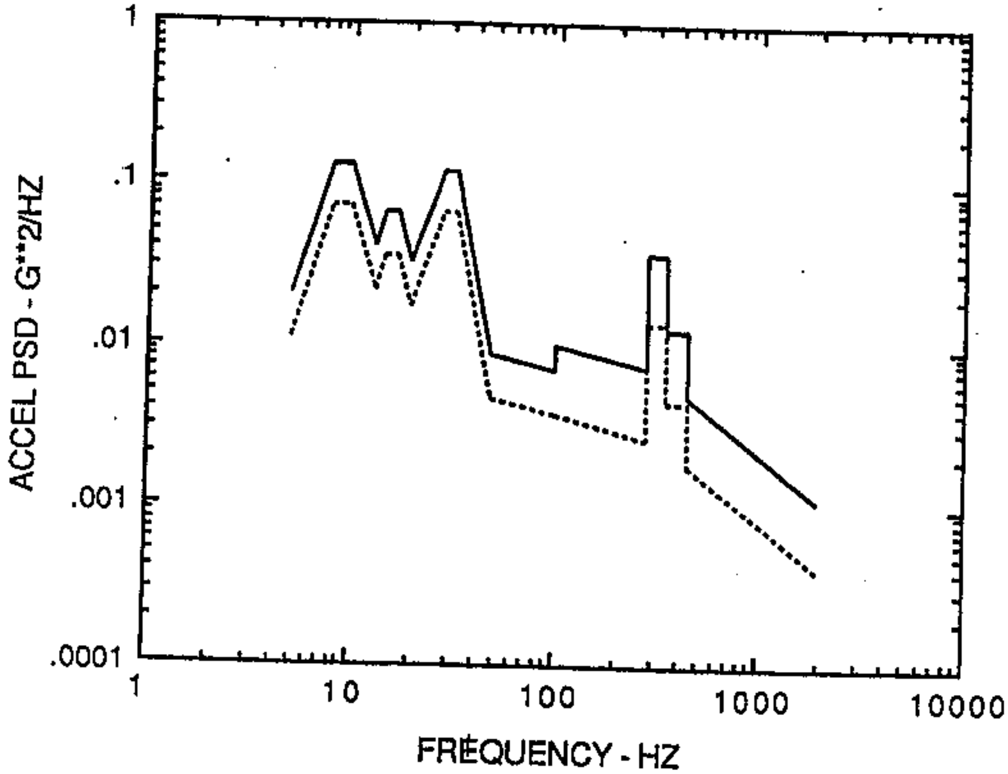
Figure 2
Region 1 - Forward Fuselage and Avionics Equipment Bay
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

······· Performance - 0.5 hrs/axis		——— Endurance - 2.0 hrs/axis	
g_{rms} overall =	6.08	g_{rms} overall =	10.01
f (Hz)	Level (g²/Hz or dB/oct)	f (Hz)	Level (g²/Hz or dB/oct)
5-8	12.0	5-8	12.0
8-10	0.069	8-10	0.128
10-13.3	-12.4	10-13.3	-12.4
13.3-15	12.1	13.3-15	12.1
15-17	0.035	15-17	0.064
17-20	-13.4	17-20	-13.4
20-28	11.9	20-28	11.9
28-33	0.063	28-33	0.117
33-50	-20.0	33-50	-20.0
50-355	0.0040	50-100	0.0074
355-562	0.044	100-355	0.011
562-708	0.075	355-562	0.121
708	0.0308	562-708	0.206
708-2000	-6.0	708	0.085
		708-2000	-6.0

Figure 3
Region 2 - Crew Station Area
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

••••••• Performance - 0.5 hrs/axis

g_{rms} overall = 2.19

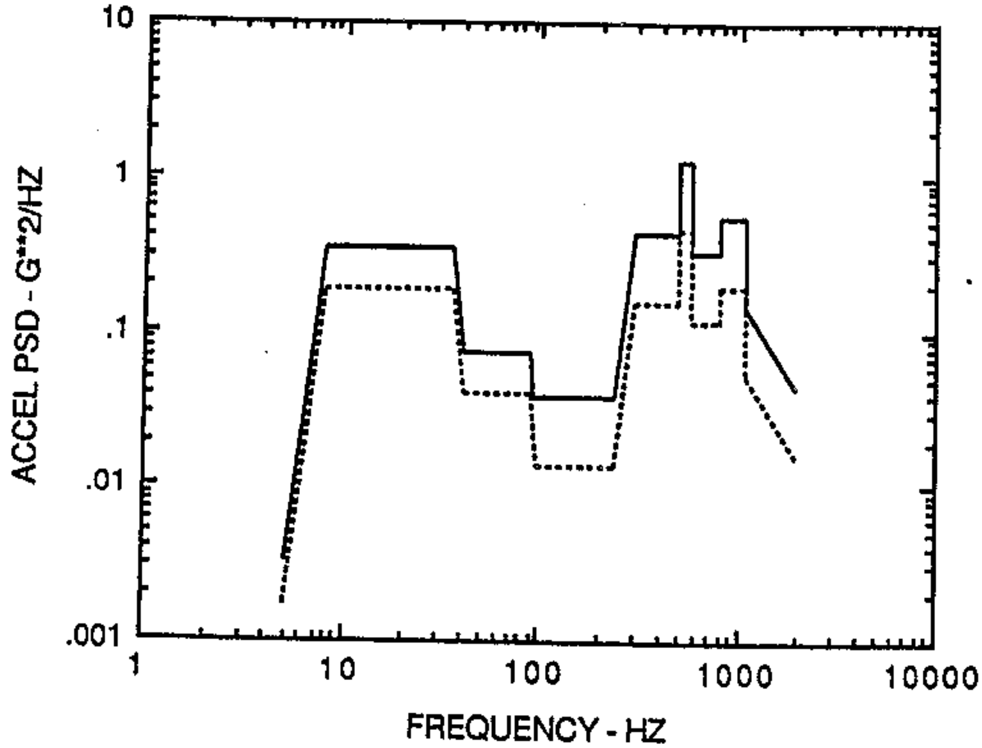
f (Hz)	Level (g^2/Hz or dB/oct)
5-8	12.0
8-10	0.069
10-13.3	-12.4
13.3-15	12.1
15-17	0.035
17-20	-13.4
20-28	11.9
28-33	0.063
33-49	-20.0
49-282	-1.0
282-355	0.013
355-447	0.0044
447	0.0018
447-2000	-3.0

——— Endurance - 2.0 hrs/axis

g_{rms} overall = 3.42

f (Hz)	Level (g^2/Hz or dB/oct)
5-8	12.0
8-10	0.128
10-13.3	-12.4
13.3-15	12.1
15-17	0.064
17-20	-13.4
20-28	11.9
28-33	0.117
33-49	-20.0
49-100	-1.0
100	0.010
100-282	-1.0
282-355	0.036
355-447	0.012
447	0.0049
447-2000	-3.0

Figure 4
Region 3 - Center Fuselage
Non-Gunfire Random Vibration Test Levels



<u>Vibration Test Curves Definition</u>

········ Performance - 0.5 hrs/axis

g_{rms} overall = 13.72

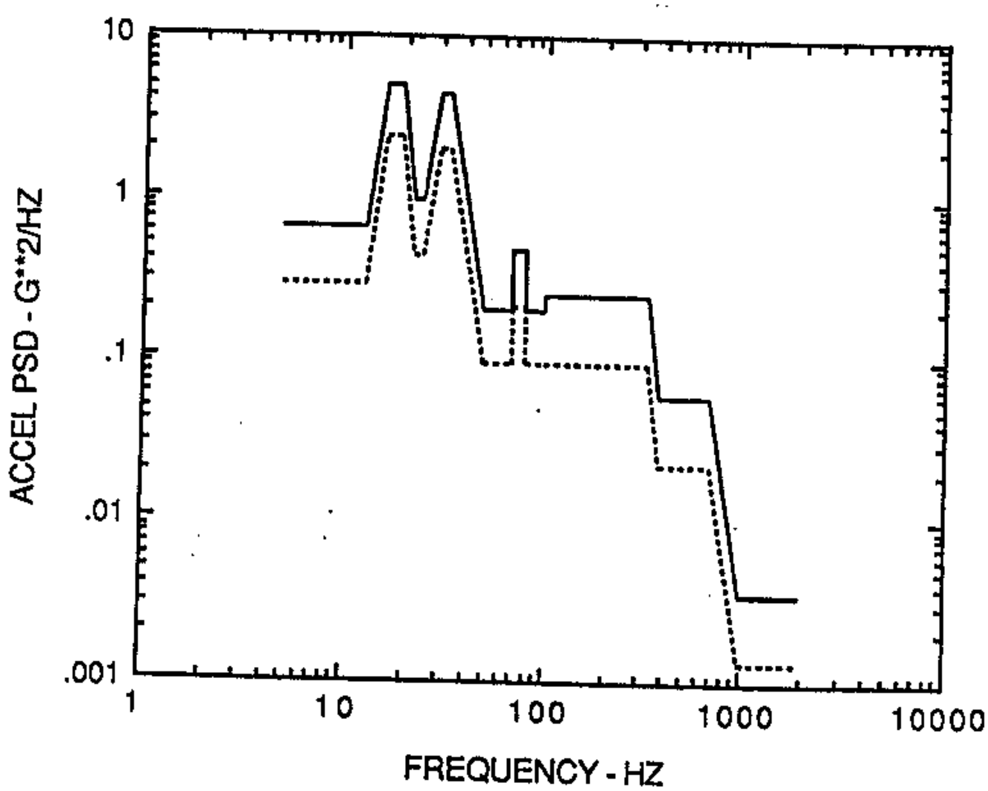
f (Hz)	Level (g^2/Hz or dB/oct)
5-8	30.0
8-36	0.185
36-42	-30.0
42-90	0.039
90-100	-30.0
100-235	0.014
235-300	30.0
300-500	0.155
500-575	0:451
575-800	0.116
800-1100	0.193
1100	0.052
1100-2000	-6.0

——— Endurance - 2.0 hrs/axis

g_{rms} overall = 22.62

f (Hz)	Level (g^2/Hz or dB/oct)
5-8	30.0
8-36	0.342
36-42	-30.0
42-90	0.072
90-96	-30.0
96-235	0.038
235-300	30.0
300-500	0.426
500-575	1.244
575-800	0.320
800-1100	0.533
1100	0.142
1100-2000	-6.0

Figure 5
Region 4A - Empennage Booms
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

Performance - 0.5 hrs/axis

g_{rms} overall = 8.84

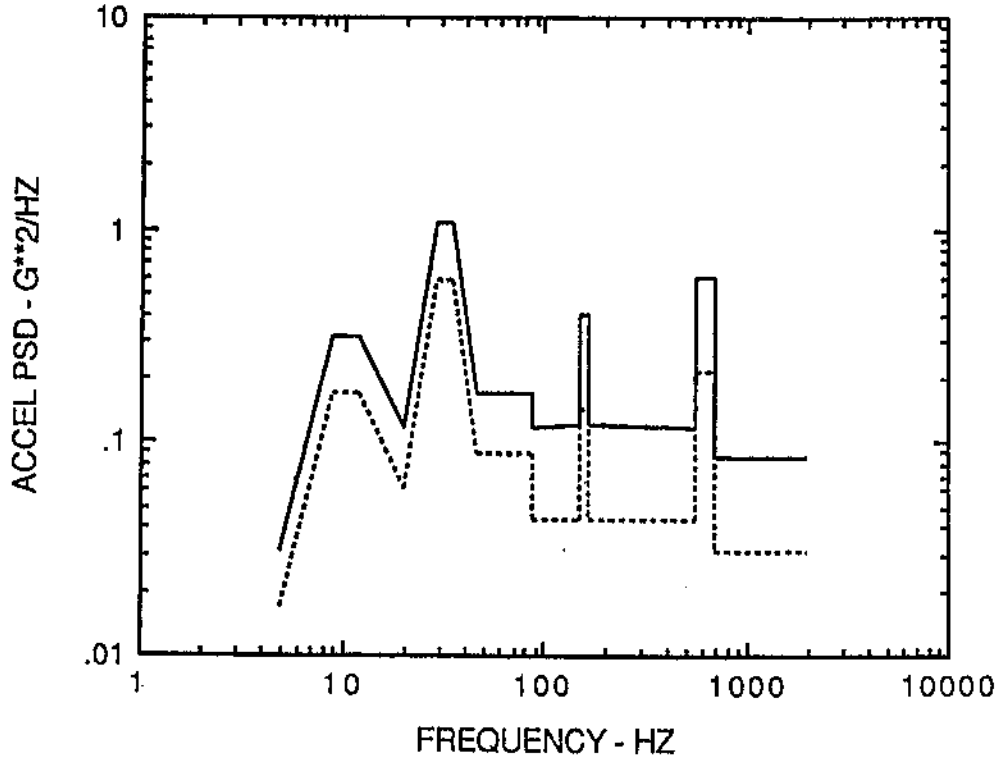
f (Hz)	Level (g^2/Hz or dB/oct)
5-13	0.284
13-16	30.0
16-19	2.249
19-22.5	-30.0
22.5-24.8	0.422
24.8-30	24.0
30-34	1.940
34-50	-24.0
50-70	0.090
70-80	0.208
80-340	0.090
340-392	-30.0
392-700	0.022
700-1000	-24.0
1000-2000	0.0013

Endurance - 2.0 hrs/axis

g_{rms} overall = 13.79

f (Hz)	Level (g^2/Hz or dB/oct)
5-13	0.622
13-16	30.0
16-19	4.926
19-22.5	-30.0
22.5-24.8	0.924
24.8-30	24.0
30-34	4.249
34-50	-24.0
50-70	0.196
70-80	0.455
80-100	0.196
100-340	0.247
340-392	-30.0
392-700	0.060
700-1000	-24.0
1000-2000	0.0036

Figure 6
Region 4B - Aft Fuselage
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

······· Performance - 0.5 hrs/axis

g_{rms} overall = 10.33

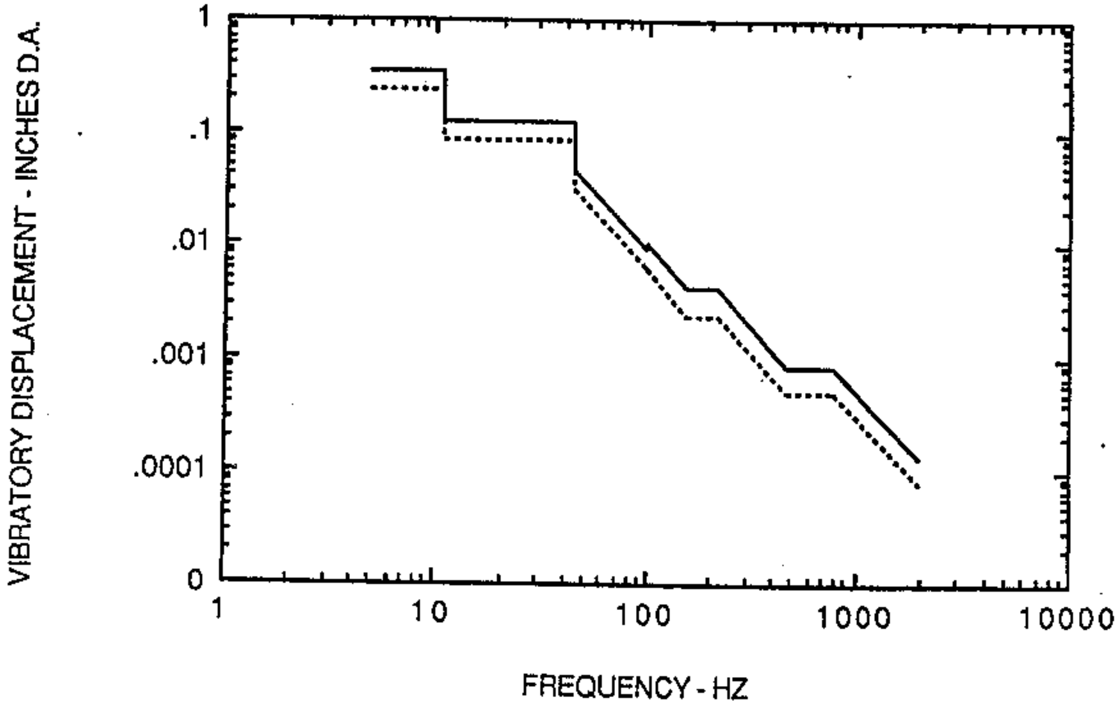
f (Hz)	Level (g^2/Hz or dB/oct)
5-9	12.0
9-12	0.171
12-20	-6.0
20-28	20.0
28-34	0.577
34-45	-20.0
45-89	0.090
89-150	0.043
150-170	0.140
170-562	0.043
562-708	0.215
708-2000	0.031

——— Endurance - 2.0 hrs/axis

g_{rms} overall = 16.78

f (Hz)	Level (g^2/Hz or dB/oct)
5-9	12.0
9-12	0.316
12-20	-6.0
20-28	20.0
28-34	1.067
34-45	-20.0
45-89	0.166
89-150	0.118
150-170	0.390
170-562	0.118
562-708	0.592
708-2000	0.084

Figure 7
Region 4C - Auxiliary Power Unit Bay*
Non-Gunfire Sinusoidal Vibration Test Levels



Vibration Test Curves Definition

········ Performance

f (Hz)	Level (in. d.a. or g's)
5-11	0.23 in
11-45	0.080 in
45-158	±3.0 g
158-221	0.0024 in
221-480	±5.9 g
480-790	0.00050 in
790-2000	±16.0 g

——— Endurance

f (Hz)	Level (in. d.a. or g's)
5-11	0.34 in
11-45	0.12 in
45-100	±4.4 g
100-158	±5.1 g
158-221	0.004 in
221-480	±10.0 g
480-790	0.00085 in
790-2000	±27.0 g

*See Figure 8 for description of test duration.

Note: Inertia relief is not applicable in auxiliary power unit bay vibration region.

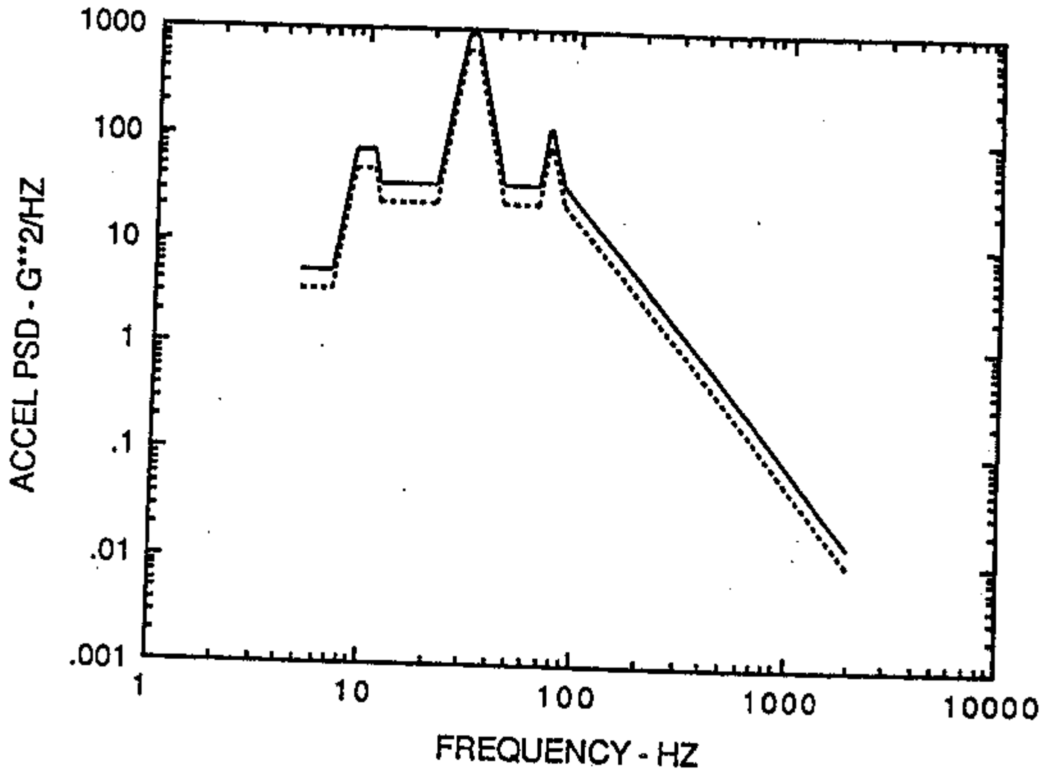
Figure 8
Non-Gunfire Sinusoidal Vibration Test Schedule
For Region 4C (Auxiliary Power Unit Bay)

Number of Resonances		0	1	2	3	4
Total Dwell Time at Resonant Points	Endurance	0	30	60	90	120
	Performance	0	5*	10*	15*	20*
Total Cycling Time	Endurance	180	150	120	90	60
	Performance	60	60	60	60	60

All test times are per axis in minutes.

*NOTE: Resonance dwell during performance testing shall be for the period required to establish performance compliance but not less than five minutes for each resonance.

Figure 9
Region 5 - Vertical Tail Tip Lateral Axis*
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

******** Performance - 0.5 hrs

g_{rms} overall = 91.2

f (Hz)	Level (g^2/Hz or dB/oct)
5-7	3.251
7-9	32.0
9-11	47.02
11-11.8	-32.0
11.8-22	22.37
22-30	32.0
30-33	604.6
33-45	-32.0
45-65	22.37
65-73	32.0
73-76	76.82
76-86	-32.0
86-2000	-7.5

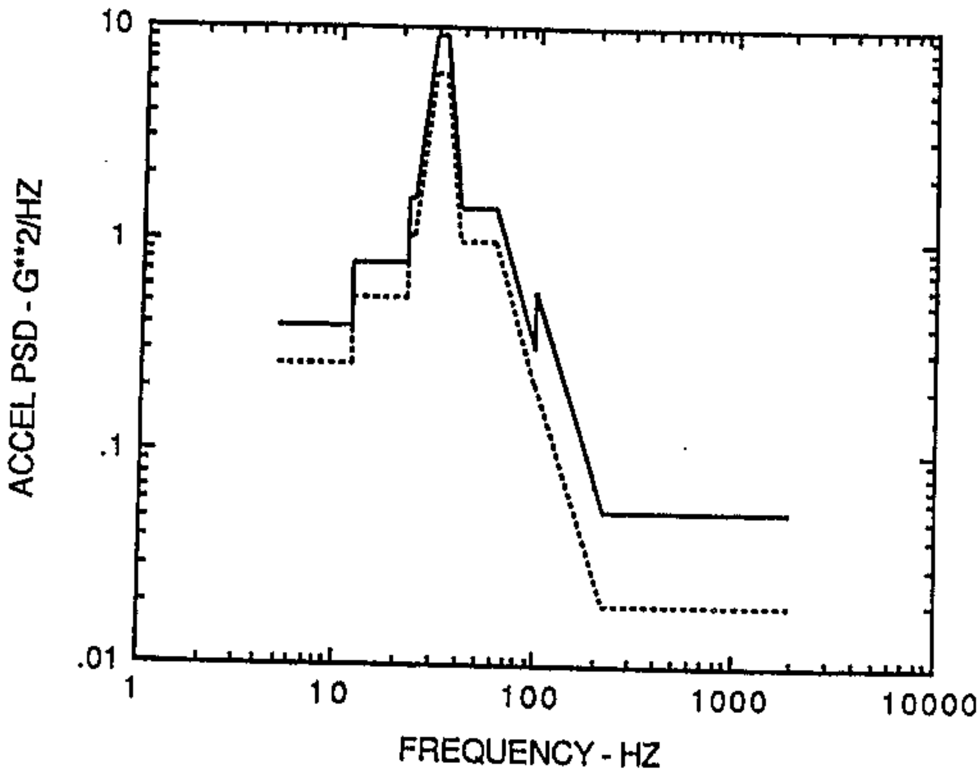
——— Endurance - 2.0 hrs

g_{rms} overall = 111.3

f (Hz)	Level (g^2/Hz or dB/oct)
5-7	4.839
7-9	32.0
9-11	69.99
11-11.8	-32.0
11.8-22	33.29
22-30	32.0
30-33	900.0
33-45	-32.0
45-65	33.29
65-73	32.0
73-76	114.3
76-86	-32.0
86-2000	-7.5

*See Figure 17 for description of lateral levels at intermediate tail Water Line locations.

Figure 10
Region 5 - Vertical Tail Longitudinal and Vertical Axes
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

.... Performance - 0.5 hrs/axis

g_{rms} overall = 12.17

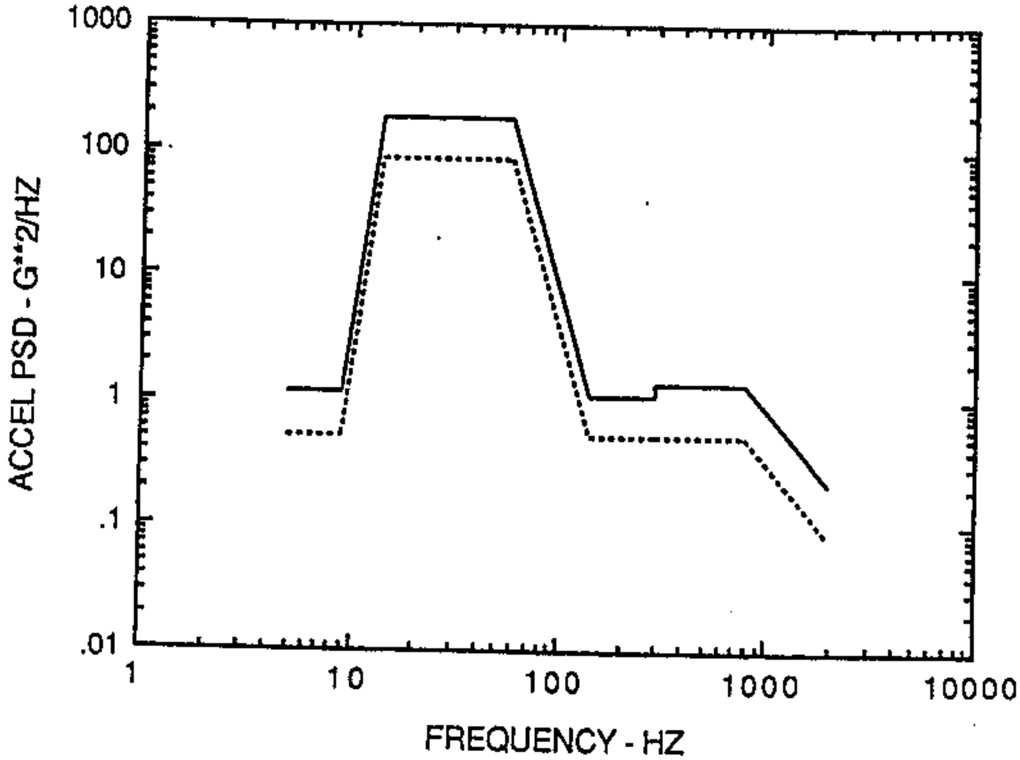
f (Hz)	Level (g^2/Hz or dB/oct)
5-12	0.257
12-22	0.514
22-24	1.027
24-30	24.0
30-34	6.083
34-41	-30.0
41-60	0.942
60-220	-9.0
220-2000	0.019

——— Endurance - 2.0 hrs/axis

g_{rms} overall = 16.56

f (Hz)	Level (g^2/Hz or dB/oct)
5-12	0.382
12-22	0.764
22-24	1.529
24-30	24.0
30-34	9.054
34-41	-30.0
41-60	1.401
60-100	-9.0
100	0.563
100-220	-9.0
220-2000	0.053

Figure 11
Region 6 - Stabilator Tip Vertical Axis*
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

******** Performance - 0.5 hrs

g_{rms} overall = 73.92

f (Hz)	Level (g^2/Hz or dB/oct)
5-9	0.512
9-14	34.6
14-60	83.10
60-142	-18.0
142-800	0.488
800-2000	-6.0

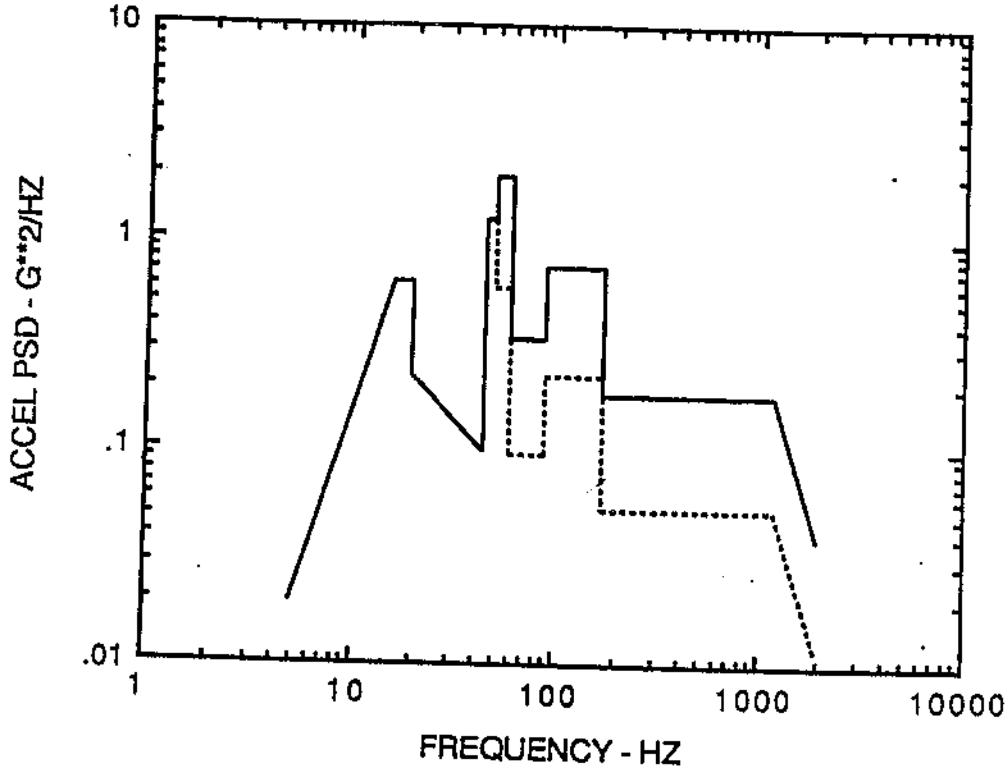
——— Endurance - 2.0 hrs

g_{rms} overall = 110.6

f (Hz)	Level (g^2/Hz or dB/oct)
5-9	1.120
9-14	34.6
14-60	182.1
60-142	-18.0
142-300	1.070
300-800	1.346
800-2000	-6.0

*See Figure 17 for description of vertical levels at intermediate stabilator Buttock Line locations

Figure 12
Region 6 - Stabilator Lateral and Longitudinal Axes
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

Performance - 0.5 hrs/axis

g_{rms} overall = 10.7

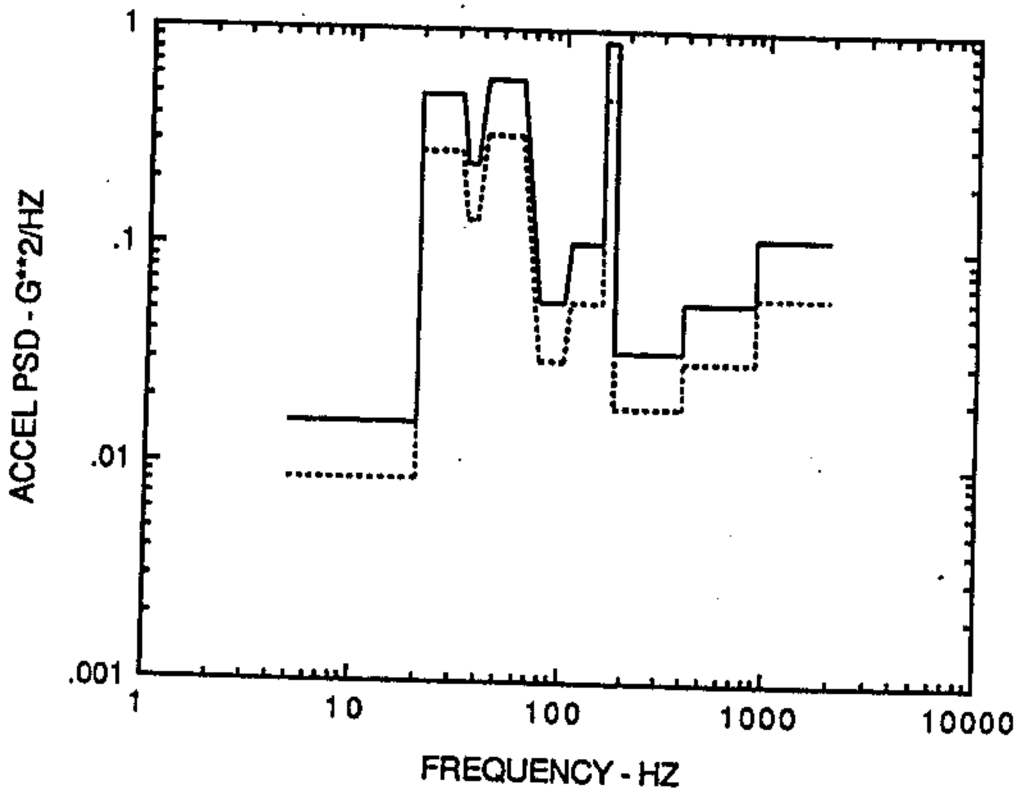
f (Hz)	Level (g^2/Hz or dB/oct)
5-16	9.0
16-20	0.610
20	0.220
20-45	-3.0
45-50	1.200
50-60	0.570
60-90	0.096
90-170	0.220
170-1200	0.053
1200-2000	-9.0

Endurance - 2.0 hrs/axis

g_{rms} overall = 18.9

f (Hz)	Level (g^2/Hz or dB/oct)
5-16	9.0
16-20	0.610
20	0.220
20-45	-3.0
45-50	1.200
50-60	1.940
60-90	0.330
90-170	0.740
170-1200	0.180
1200-2000	-9.0

Figure 13
Region 7A - Inboard Wing Vertical Axis
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

.... Performance - 0.5 hrs/axis

g_{rms} overall = 10.57

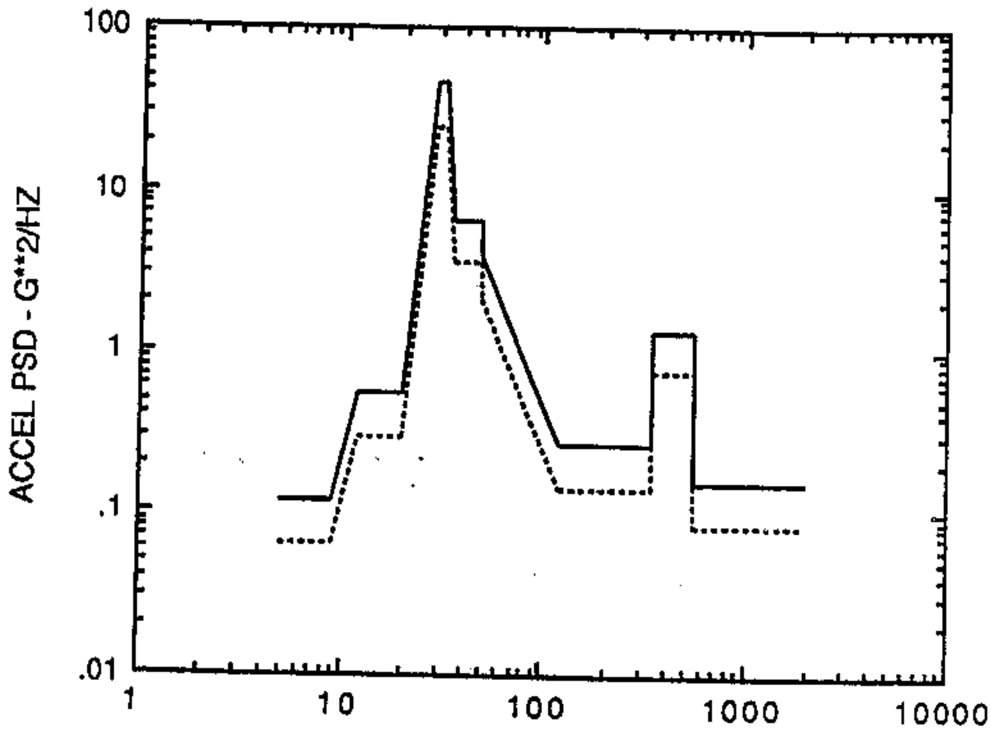
f (Hz)	Level (g^2/Hz or dB/oct)
5-20	0.0083
20-32	0.272
32-34	-36.0
34-39	0.132
39-42	36.0
42-63	0.319
63-77	-35.4
77-105	0.030
105-112	29.3
112-160	0.056
160-180	0.477
180-400	0.018
400-900	0.030
900-2000	0.060

——— Endurance - 2.0 hrs/axis

g_{rms} overall = 14.37

f (Hz)	Level (g^2/Hz or dB/oct)
5-20	0.015
20-32	0.503
32-34	-36.0
34-39	0.243
39-42	36.0
42-63	0.590
63-77	-35.4
77-105	0.055
105-112	29.3
112-160	0.104
160-180	0.883
180-400	0.033
400-900	0.055
900-2000	0.111

Figure 14
Region 7B - Mid Wing Vertical Axis
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

.... Performance - 0.5 hrs

g_{rms} overall = 23.73

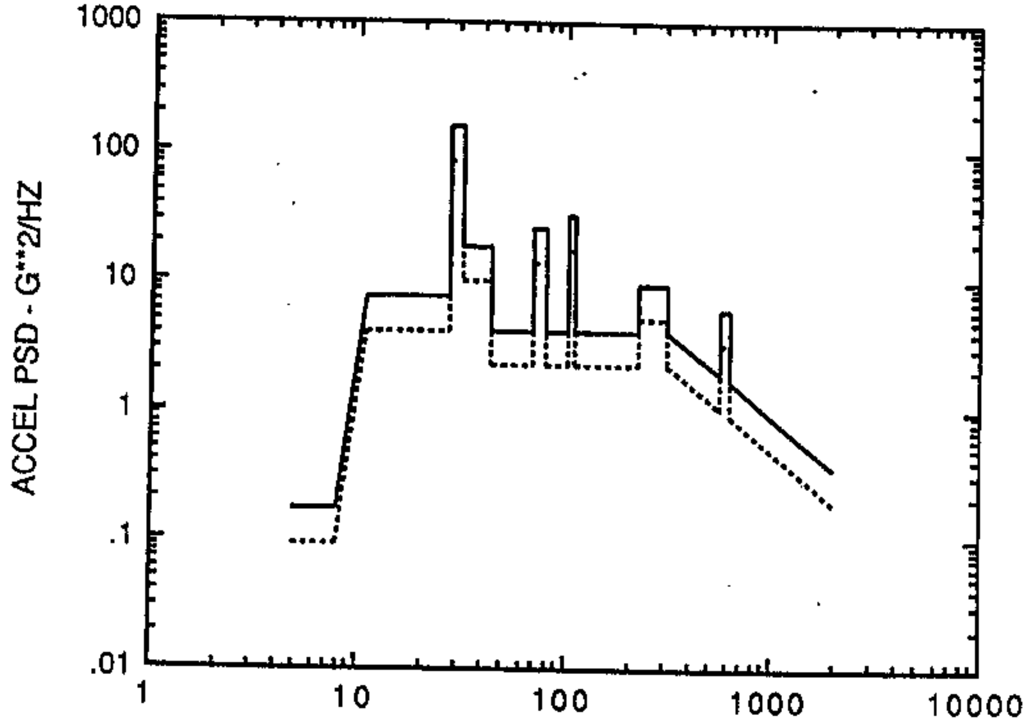
f (Hz)	Level (g^2/Hz or dB/oct)
5-9	0.062
9-12	16.0
12-20	0.287
20-29	36.0
29-32	24.44
32-36	-50.0
36-50	3.455
50	2.075
50-123	-9.0
123-355	0.139
355-563	0.716
563-2000	0.082

———— Endurance - 2.0 hrs

g_{rms} overall = 32.27

f (Hz)	Level (g^2/Hz or dB/oct)
5-9	0.115
9-12	16.0
12-20	0.531
20-29	36.0
29-32	45.20
32-36	-50.0
36-50	6.390
50	3.838
50-123	-9.0
123-355	0.257
355-563	1.323
563-2000	0.151

Figure 15
Region 7C - Outer Wing Vertical Axis
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

········ Performance - 0.5 hrs

g_{rms} overall = 51.53

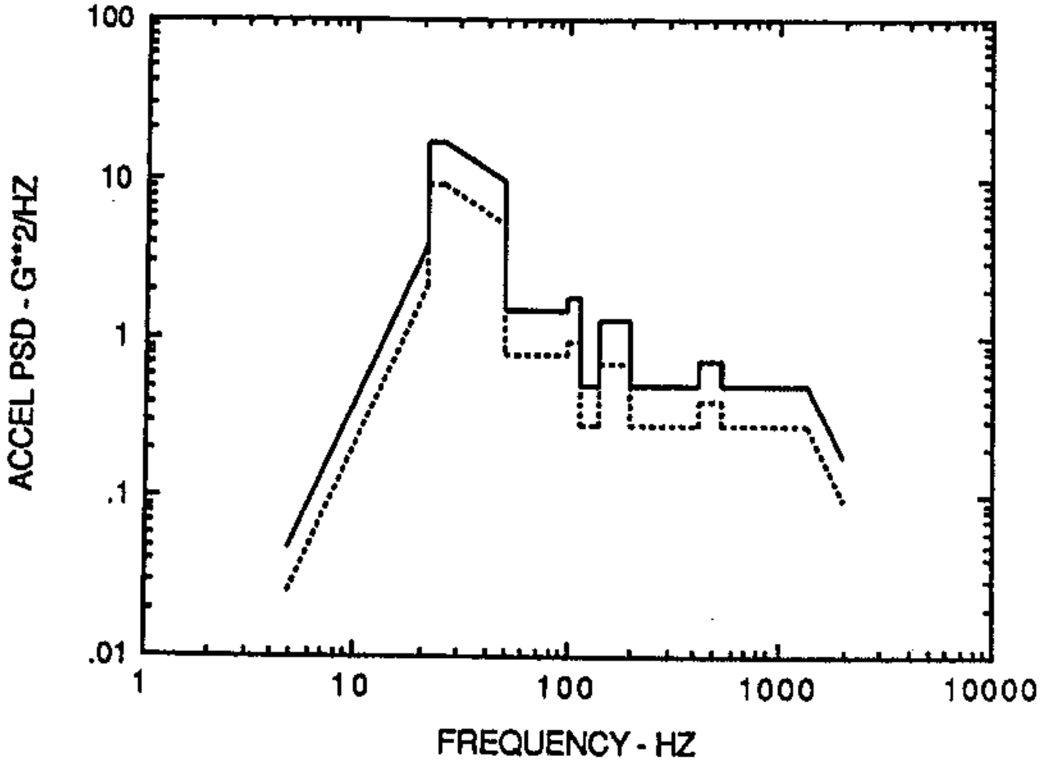
f (Hz)	Level (g^2/Hz or dB/oct)
5-8	0.088
8-11	36.0
11-28	3.963
28-32	80.46
32-45	9.495
45-71	2.198
71-80	13.25
80-105	2.153
105-112	17.36
112-224	2.153
224-315	4.964
315	2.153
315-562	-4.0
562-630	3.222
630	0.856
630-2000	-4.0

——— Endurance - 2.0 hrs

g_{rms} overall = 70.09

f (Hz)	Level (g^2/Hz or dB/oct)
5-8	0.163
8-11	36.0
11-28	7.330
28-32	148.8
32-45	17.56
45-71	4.065
71-80	24.52
80-105	3.982
105-112	32.11
112-224	3.982
224-315	9.181
315	3.982
315-562	-4.0
562-630	5.960
630	1.584
630-2000	-4.0

Figure 16
Region 7 - Wing Tip Lateral and Longitudinal Axes*
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

•••••••• Performance - 0.5 hrs/axis

g_{rms} overall = 27.27

f (Hz)	Level (g^2/Hz or dB/oct)
5-22	9.0
22	2.100
22-26	8.900
26-50	-2.6
50-100	0.780
100-115	0.950
115-140	0.270
140-200	0.682
200-425	0.270
425-550	0.393
550-1400	0.270
1400-2000	-9.0

——— Endurance - 2.0 hrs/axis

g_{rms} overall = 37.09

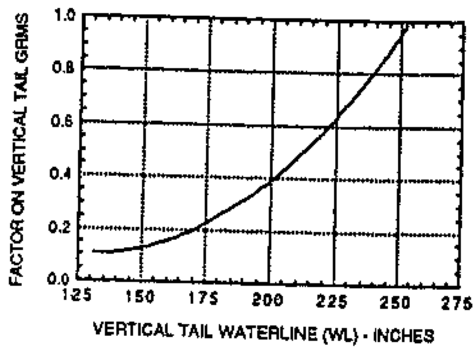
f (Hz)	Level (g^2/Hz or dB/oct)
5-22	9.0
22	3.884
22-26	16.46
26-50	-2.6
50-100	1.443
100-115	1.757
115-140	0.500
140-200	1.261
200-425	0.500
425-550	0.727
550-1400	0.500
1400-2000	-9.0

*See Figure 17 for description of lateral and longitudinal levels at intermediate wing Buttock Line locations.

Figure 17
Lifting Surface Non-Gunfire Random Vibration
Proportionality Factors

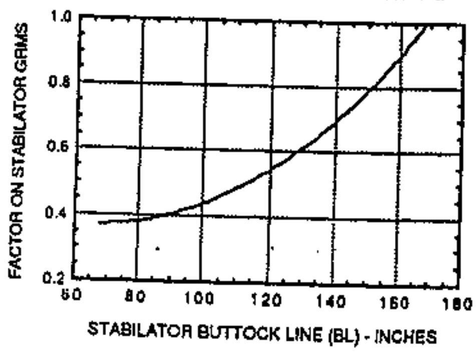
To determine the overall grms at an intermediate location within the lifting surface, multiply the tip level grms specified (Figure 9, 11, or 16) by the applicable proportionality factor specified below.

REGION 5 - VERTICAL TAIL LATERAL



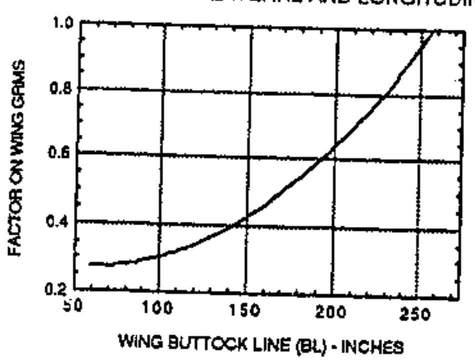
$$\text{Factor on GRMS} = 0.1 + \left(\left(\frac{WL - 130}{124} \right)^2 \times 0.9 \right)$$

REGION 6 - STABILATOR VERTICAL



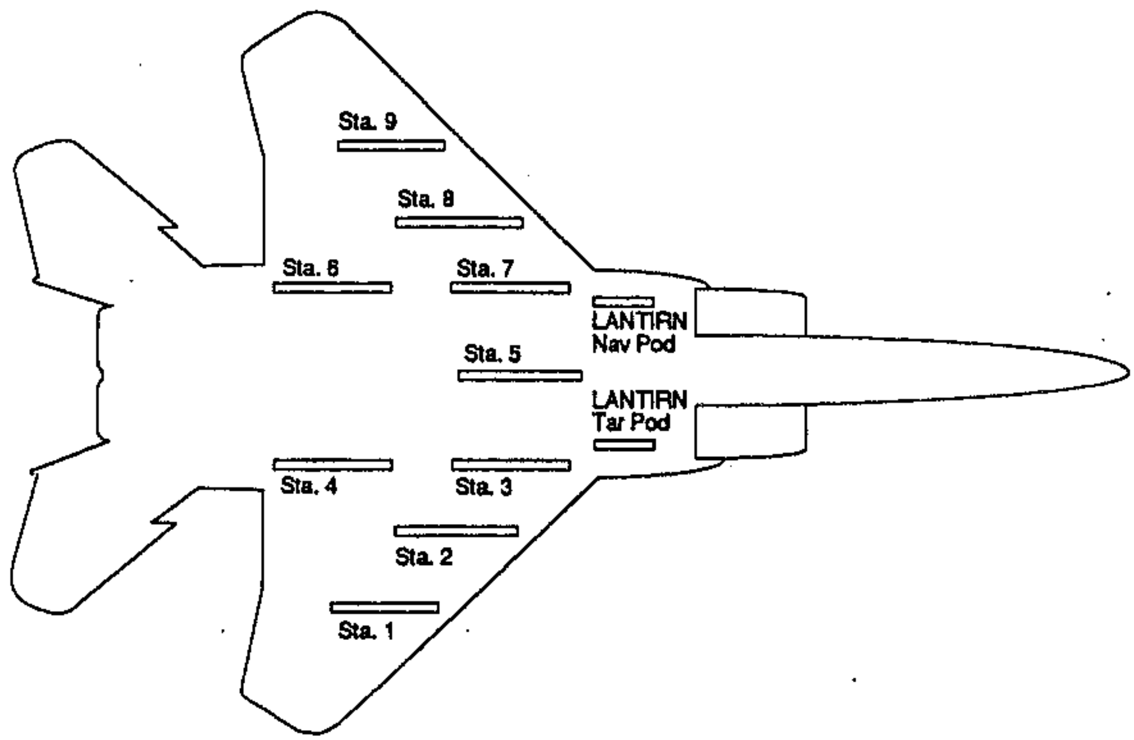
$$\text{Factor on GRMS} = 0.37 + \left(\left(\frac{BL - 68}{101} \right)^2 \times 0.63 \right)$$

REGION 7 - WING LATERAL AND LONGITUDINAL



$$\text{Factor on GRMS} = 0.27 + \left(\left(\frac{BL - 59.5}{198.5} \right)^2 \times 0.73 \right)$$

Figure 18
Weapons Stations Vibration Regions
For Non-CFT Locations



Station5
Region 8A - Centerline Pylon
Region 8B - ASAT Missile
Region 8C - SRAM T Missile

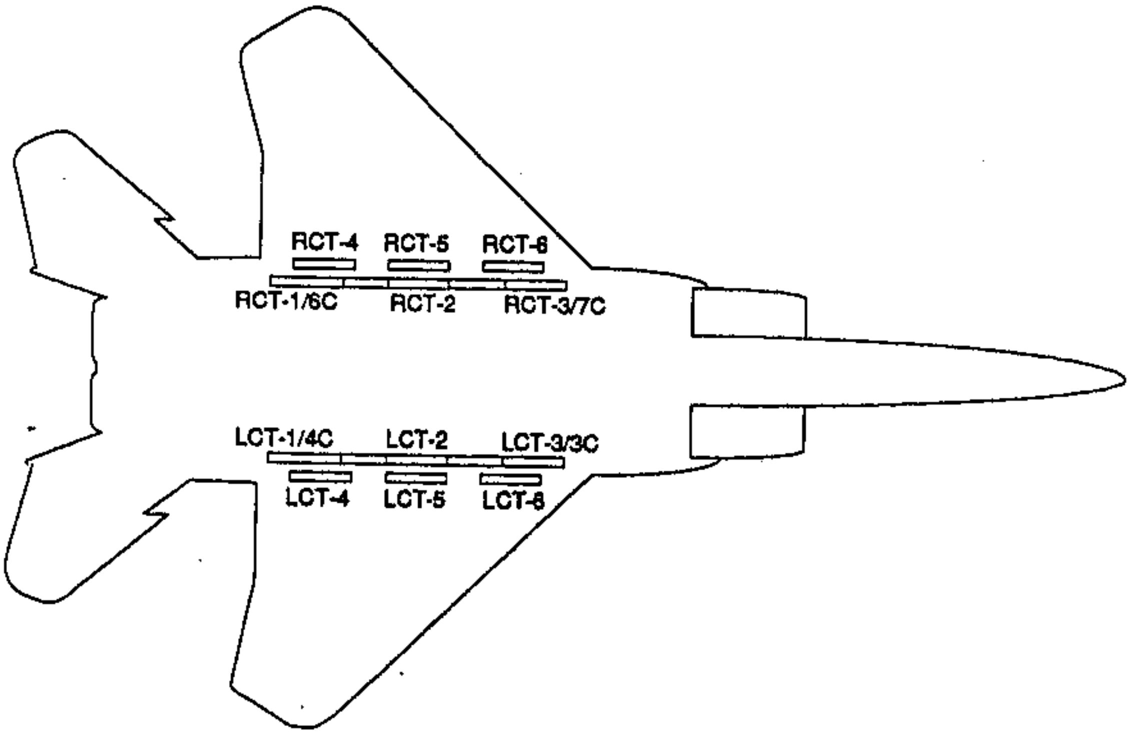
LANTIRN
Region 8D - Navigation Pod
Region 8E - Targeting Pod

Stations 3, 4, 6, and 7
Region 9A- Fuselage Air-to-Air Weapons Stations
Region 9B - AIM-7
Region 9C - AIM-120

Stations 2 and 8
Region 10A - Wing Inboard Pylon and Pylon Shoulder Stations
Region 10B - Shoulder Mounted AIM-9 + LAU-128
Region 10C - Shoulder Mounted AIM-120 + LAU-128
Region 10D - AGM-65 + LAU-117 or LAU-88
Region 10E - GBU-15
Region 10F - SRAM T + Multipurpose Adapter

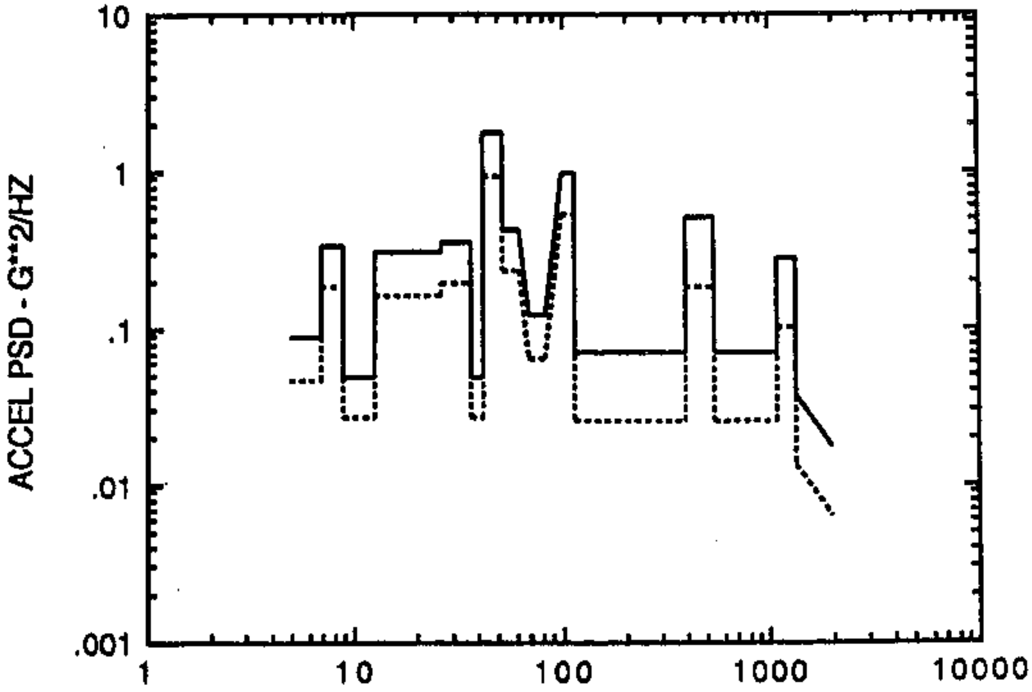
Stations 1 and 9
Region 11A - Wing Outboard Pylon

Figure 19
CFT Weapons Stations Vibration Regions



CFT Stations
Region 9A - All Air-to-Air and Air-to-Ground Weapons Stations
Region 9D - AIM-120 (Sta. C3, C4, C6, and C7)

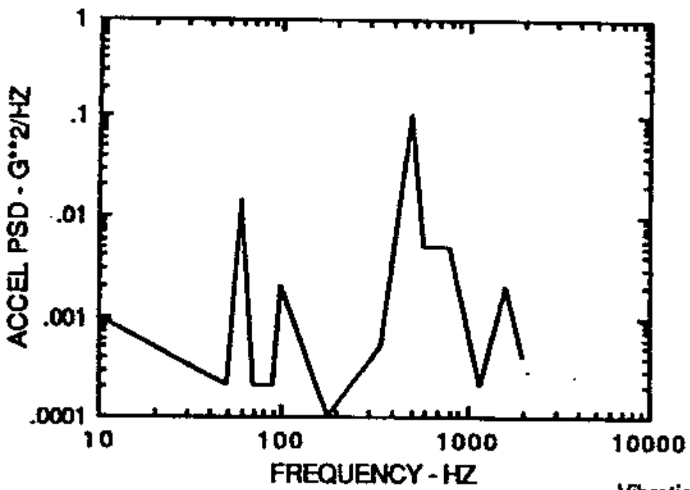
Figure 20
Region 8A - Centerline Pylon Weapons Station 5
Non-Gunfire Random Vibration Test Levels

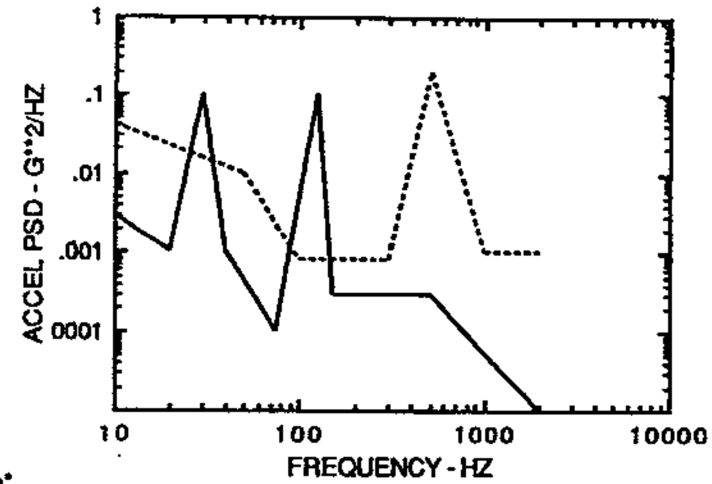


Vibration Test Curves Definition

Performance - 0.5 hrs/axis		Endurance - 2.0 hrs/axis	
g_{rms} overall =	10.65	g_{rms} overall =	16.90
f (Hz)	Level (g^2/Hz or dB/oct)	f (Hz)	Level (g^2/Hz or dB/oct)
5-7	0.047	5-7	0.086
7-9	0.180	7-9	0.333
9-13	0.026	9-13	0.048
13-27	0.160	13-27	0.296
27-37	0.190	27-37	0.351
37-42	0.026	37-42	0.048
42-52	0.927	42-52	1.716
52-63	0.225	52-63	0.417
63-70	-36.0	63-70	-36.0
70-84	0.064	70-84	0.118
84-100	36.0	84-100	36.0
100-115	0.522	100-115	0.965
115-400	0.025	115-400	0.070
400-550	0.180	400-550	0.496
550-1100	0.025	550-1100	0.070
1100-1400	0.100	1100-1400	0.276
1400	0.013	1400	0.036
1400-2000	-6.0	1400-2000	-6.0

Figure 21
Region 8B - ASAT Missile Centerline Pylon Carriage Weapons Station 5
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition*

Non-Buffet

——— Lower Stage Performance
7 hrs/axis/1000 flt hrs

g_{rms} overall = 2.94

f (Hz)	Level (g^2/Hz or dB/oct)
10	0.002
10-50	-4.3
50-60	71.0
60-70	-84.0
70-90	0.0002
90-100	65.6
100-180	-15.3
180	0.0001
180-350	7.3
350-500	44.6
500-600	-49.3
600-800	0.005
800-1200	-23.8
1200-1600	24.0
1600-2000	-21.6

-------- Upper Stage Performance
7 hrs/axis/1000 flt hrs

g_{rms} overall =

f (Hz)	Level (g^2/Hz or dB/oct)

*Non-buffet information not available for ASAT upper stage

Buffet

——— Lower Stage Performance
2 hrs/axis/1000 flt hrs

g_{rms} overall = 1.39

f (Hz)	Level (g^2/Hz or dB/oct)
10	0.003
10-20	-4.8
20-30	34.1
30	0.100
30-40	-48.0
40-75	-11.0
75	0.0001
75-125	40.6
125-150	-95.6
150-500	0.0003
500-2000	-7.4

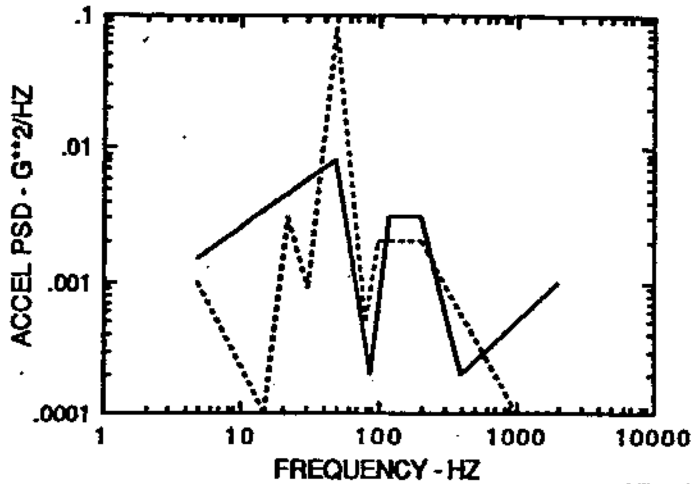
-------- Upper Stage Performance
2 hrs/axis/1000 flt hrs

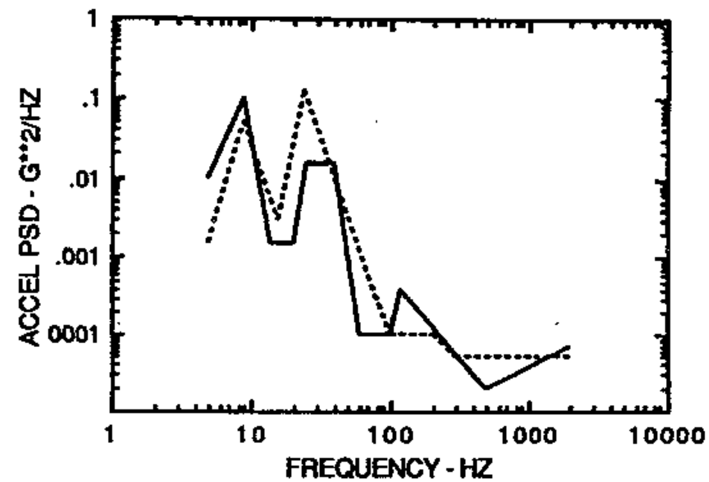
g_{rms} overall = 5.04

f (Hz)	Level (g^2/Hz or dB/oct)
10	0.040
10-50	-2.6
50-100	-10.9
100-300	0.0008
300-500	32.4
500-1000	-22.9
1000-2000	0.001

Note: Inertia relief is not applicable in Region 8B.

Figure 22
Region 8C - SRAMT Missile Centerline Pylon Carriage Weapons Station 5
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition

Non-Buffet

——— MS 46 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 1.31

f (Hz)	Level (g^2/Hz or dB/oct)
5	0.015
5-50	2.2
50-90	-18.8
90-120	28.2
120-200	0.0030
200-400	-11.7
400-2000	3.0

-------- MS 152 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 1.22

f (Hz)	Level (g^2/Hz or dB/oct)
5	0.001
5-15	-6.3
15-22	26.6
22	0.003
22-31	-10.5
31-50	28.2
50	0.080
50-80	-32.4
80-100	18.6
100-200	0.002
200-1000	-5.6
1000-2000	0.0001

Buffet

——— MS 46 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 0.84

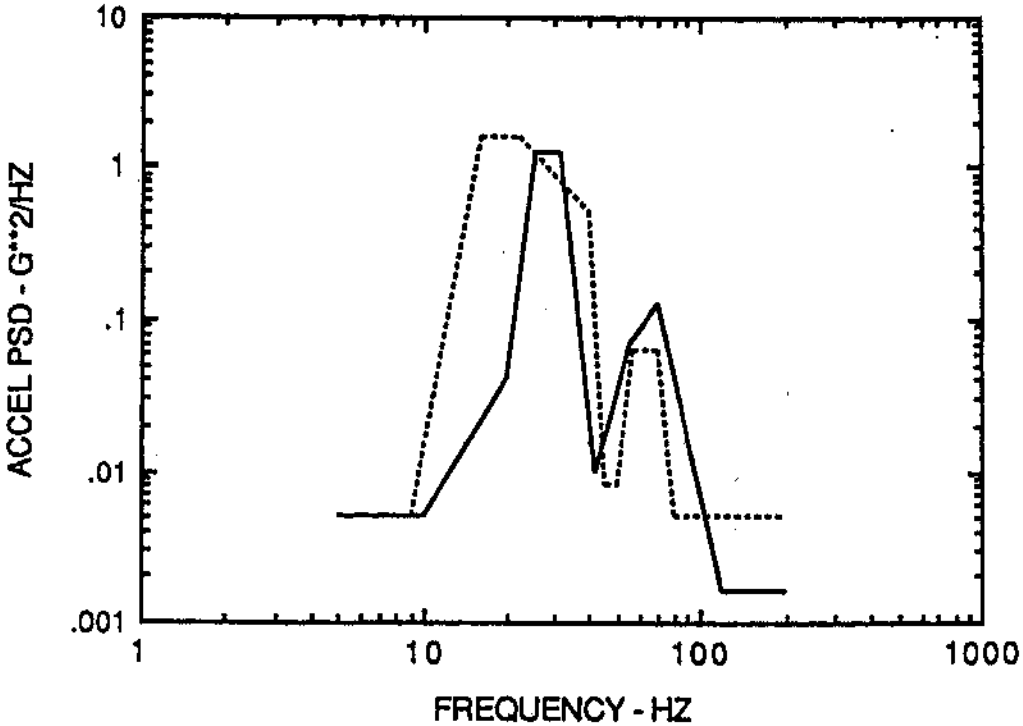
f (Hz)	Level (g^2/Hz or dB/oct)
5-9	11.8
9-14	-28.5
14-20	0.0015
20-25	31.0
25-40	0.015
40-60	-37.1
60-100	0.0001
100-120	22.8
120-500	-6.3
500-2000	2.7

-------- MS 152 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 1.13

f (Hz)	Level (g^2/Hz or dB/oct)
5	0.0015
5-9	17.9
9-16	-14.7
16-24	27.3
24	0.120
24-100	-14.9
100-200	0.0001
200-300	-5.1
300-2000	0.00005

Note: Inertia relief is not applicable in Region 8C.

Figure 23
Region 8D - LANTIRN Navigation Pod
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition*

.... Lateral Axis Performance
2 hrs/1000 flt hrs
g_{rms} overall = 5.50

f (Hz)	Level (g^2/Hz or dB/oct)
5-9	0.0050
9-16	30.0
16-22	1.580
22-40	-5.8
40-45	-106.
45-50	0.0079
50-57	47.5
57-70	0.063
70-80	-56.9
80-200	0.0050

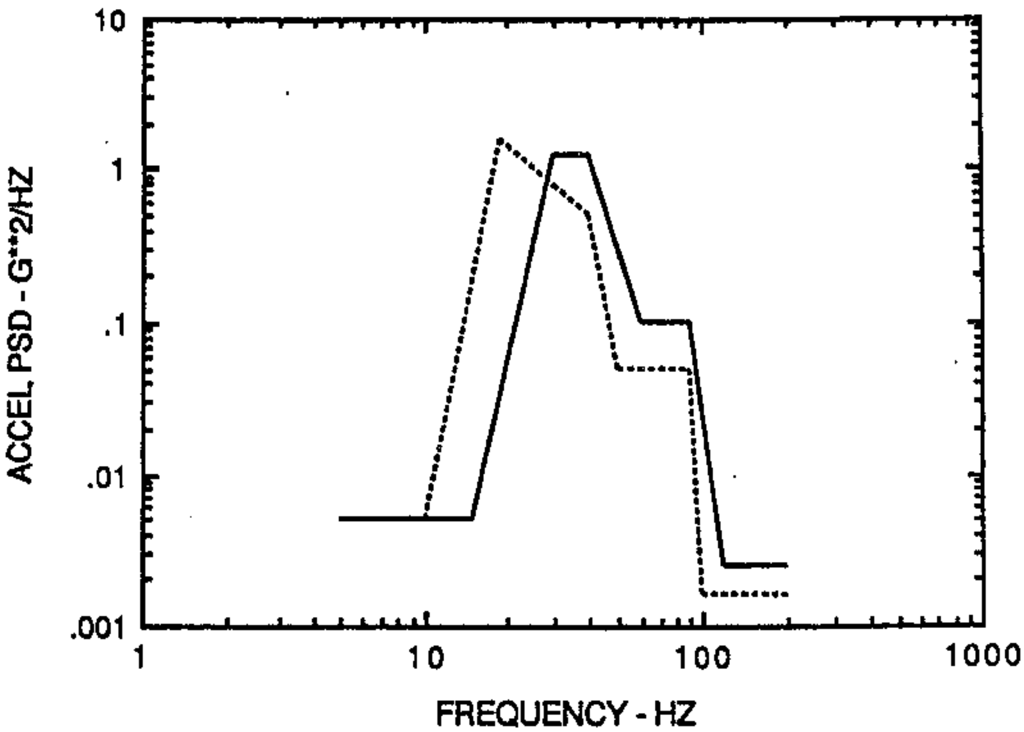
——— Vertical Axis Performance
2 hrs/1000 flt hrs
g_{rms} overall = 3.93

f (Hz)	Level (g^2/Hz or dB/oct)
5-10	0.0050
10-20	9.0
20-25	46.4
25-31	1.260
31-42	-47.8
42-55	21.6
55	0.07
55-70	7.3
70-120	-24.3
120-200	0.0016

*Information not available for longitudinal axis.

Note: Inertia relief is not applicable in Region 8D.

Figure 24
Region 8E - LANTIRN Targeting Pod
Non-Gunfire Random Vibration Test Levels



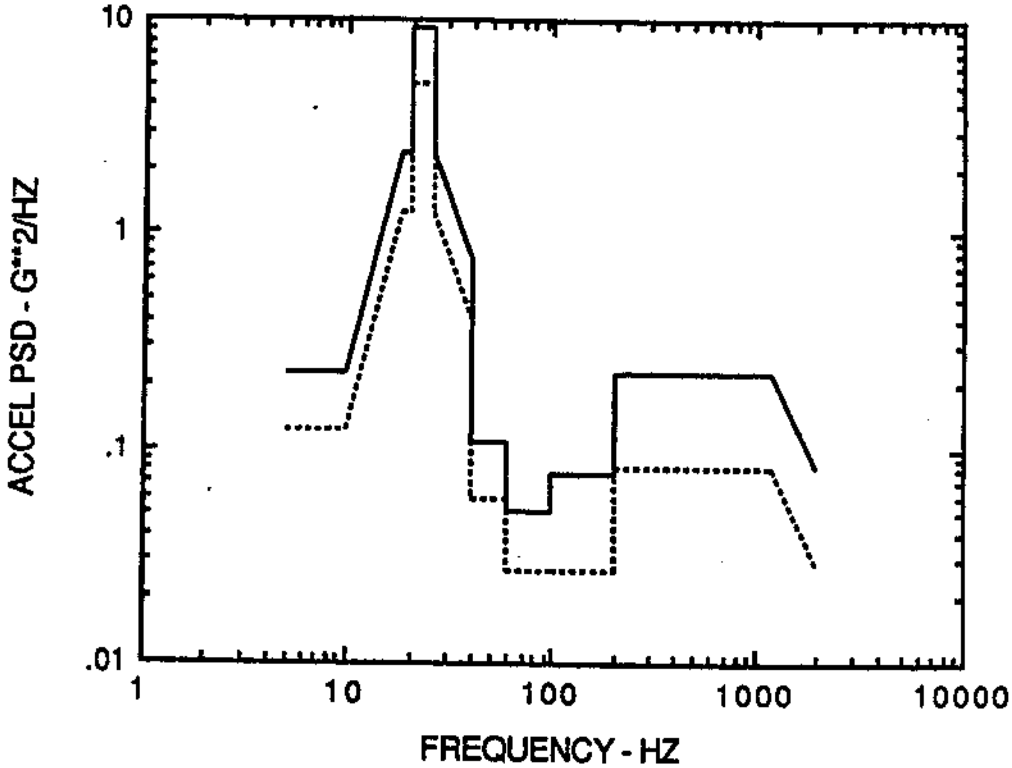
Vibration Test Curves Definition*

········ Lateral Axis Performance 2 hrs/1000 flt hrs		— Vertical Axis Performance 2 hrs/1000 flt hrs	
g_{rms} overall =	5.06	g_{rms} overall =	5.41
f (Hz)	Level (g^2/Hz or dB/oct)	f (Hz)	Level (g^2/Hz or dB/oct)
5-10	0.0050	5-15	0.0050
10-19	26.9	15-30	23.9
19-40	-4.6	30-40	1.260
40-50	-31.0	40-60	-18.7
50-90	0.050	60-90	0.100
90-100	-98.0	90-120	-38.5
100-200	0.0016	120-200	0.0025

*Information not available for longitudinal axis.

Note: Inertia relief is not applicable in Region 8E.

Figure 25
Region 9A - Fuselage Store Stations 3, 4, 6, and 7 and
CFT Air-to-Air and Air-to-Ground Weapons Stations
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

•••••••• Performance - 0.5 hrs/axis

g_{rms} overall = 13.06

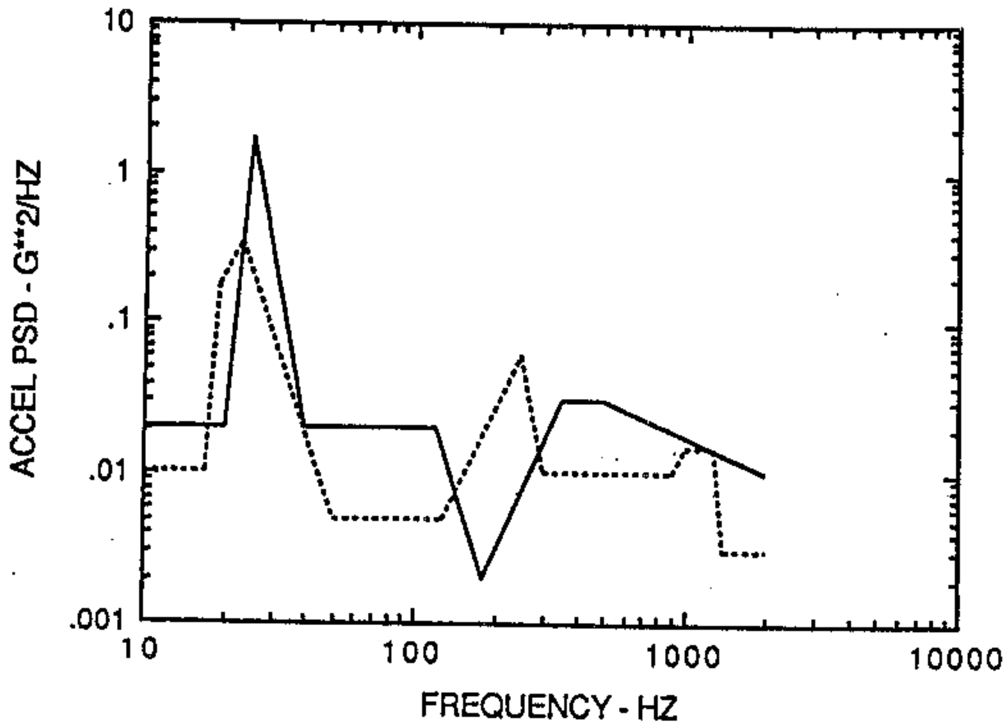
f (Hz)	Level (g^2/Hz or dB/oct)
5-10	0.120
10-18	12.0
18-20	1.250
20-26	4.950
26	1.250
26-40	-8.0
40-60	0.058
60-200	0.027
200-1200	0.080
1200-2000	-6.0

——— Endurance - 2.0 hrs/axis

g_{rms} overall = 20.62

f (Hz)	Level (g^2/Hz or dB/oct)
5-10	0.222
10-18	12.0
18-20	2.312
20-26	9.156
26	2.312
26-40	-8.0
40-60	0.107
60-100	0.050
100-200	0.074
200-1200	0.220
1200-2000	-6.0

Figure 26
Region 9B - AIM-7 Missile Fuselage Carriage Weapons Stations 3, 4, 6, and 7
Non-Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

········ Motor Performance MS 140
7 hrs/1000 flt hrs/axis

g_{rms} overall = 4.70

f (Hz)	Level (g^2/Hz or dB/oct)
10-17	0.010
17-19	78.0
19-23	10.4
23	0.344
23-50	-16.4
50-125	0.005
125-250	10.8
250-300	-29.5
300-900	0.010
900-1000	11.5
1000-1300	0.015
1300-1400	-65.2
1400-2000	0.003

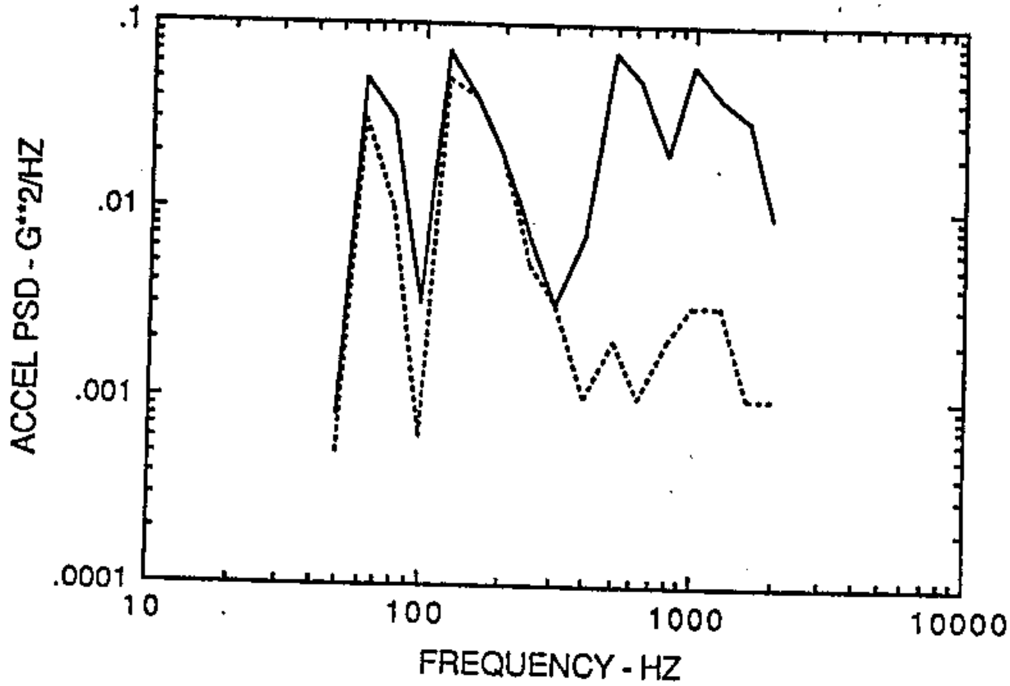
——— Gimbal Performance MS 18
7 hrs/1000 flt hrs/axis

g_{rms} overall = 6.31

f (Hz)	Level (g^2/Hz or dB/oct)
10-20	0.020
20-25	59.7
25-40	-28.4
40-120	0.020
120-180	-17.0
180-350	12.2
350-500	0.030
500-2000	-2.4

Note: Inertia relief is not applicable in Region 9B.

Figure 26.1
Region 9B - AIM-7 Missile Fuselage Carriage Weapons Station 7
Gunfire Random Vibration Test Levels



Vibration Test Curves Definition

········ Motor Performance MS 140
10 min/8000 flt hrs/axis

g_{rms} overall = 2.70

f (Hz)	Level (g^2/Hz or dB/oct)
50	0.001
63	0.030
80	0.010
100	0.001
125	0.050
160	0.040
200	0.020
250	0.005
315	0.003
400	0.001
500	0.002
630	0.001
800	0.002
1000	0.003
1250	0.003
1600	0.001
2000	0.001

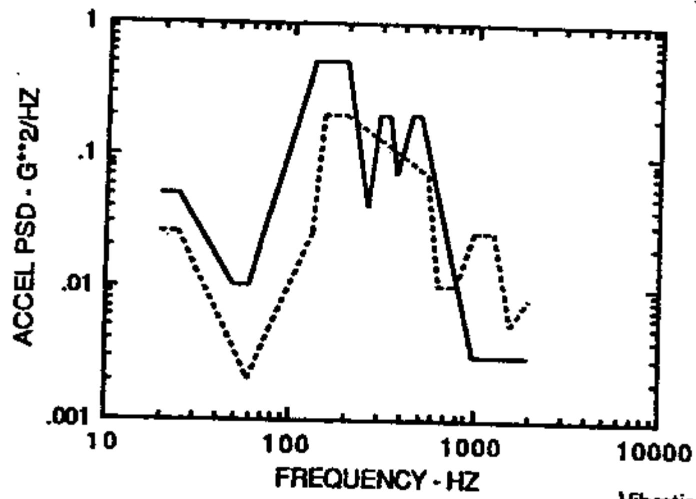
——— Gimbal Performance MS 18
10 min/8000 flt hrs/axis

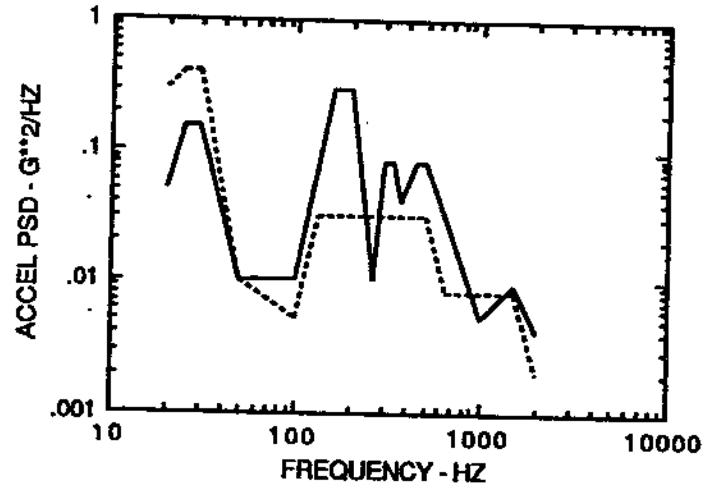
g_{rms} overall = 7.78

f (Hz)	Level (g^2/Hz or dB/oct)
50	0.001
63	0.050
80	0.030
100	0.003
125	0.070
160	0.040
200	0.020
250	0.007
315	0.003
400	0.007
500	0.070
630	0.050
800	0.020
1000	0.060
1250	0.040
1600	0.030
2000	0.009

Note: Inertia relief is not applicable in Region 9B.

Figure 27
Region 9C - AIM-120 Missile Fuselage Carriage Weapons Stations 3, 4, 6, and 7
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition

Non-Buffet

——— MS 32 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 10.77

f (Hz)	Level (g^2/Hz or dB/oct)
20-25	0.050
25-50	-7.0
50-60	0.010
60-130	15.2
130-200	0.500
200-265	-27.0
265-300	39.0
300-340	0.200
340-370	-37.3
370-440	18.2
440-500	0.200
500-1000	-18.2
1000-2000	0.003

.... MS 125 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 8.85

f (Hz)	Level (g^2/Hz or dB/oct)
20-25	0.025
25-60	-7.3
60-120	4.2
120-150	43.3
150-200	0.200
200-550	-2.7
550-650	-37.3
650-800	0.010
800-1000	12.3
1000-1300	0.025
1300-1600	-16.5
1600-2000	0.008

Buffet

——— MS 32 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 7.66

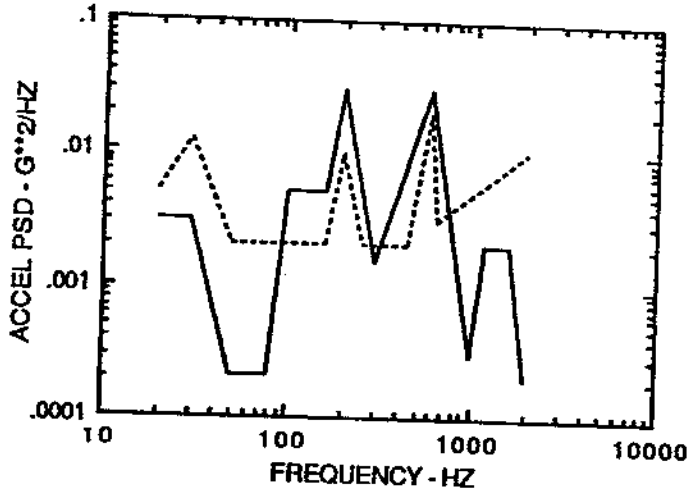
f (Hz)	Level (g^2/Hz or dB/oct)
20-25	14.8
25-30	0.150
30-50	-15.9
50-100	0.010
100-160	21.7
160-200	0.300
200-265	-36.3
265-300	50.3
300-340	0.080
340-370	-24.6
370-440	12.0
440-500	0.080
500-1000	-12.0
1000-1500	4.3
1500-2000	-8.5

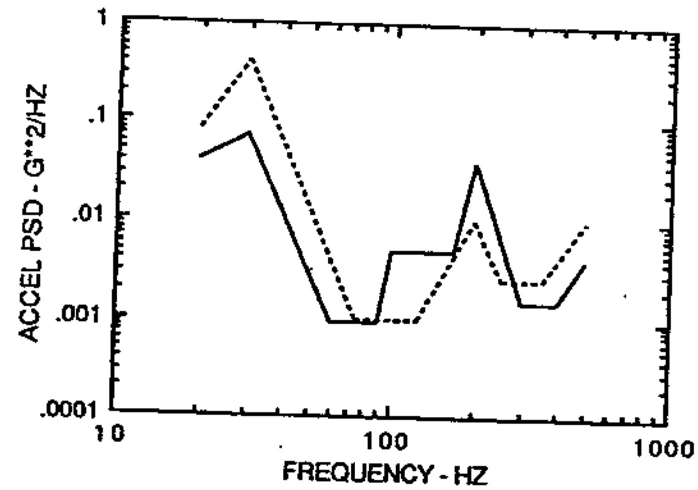
.... MS 125 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 5.37

f (Hz)	Level (g^2/Hz or dB/oct)
20-25	3.9
25-30	0.400
30-50	-21.7
50-100	-3.0
100-130	20.5
130-500	0.030
500-650	-15.1
650-1500	0.008
1500-2000	-14.5

Note: Inertia relief is not applicable in Region 9C.

Figure 28
Region 9D - AIM-120 Missile CFT Carriage Weapons Stations C3, C4, C6, and C7
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition

Non-Buffet

——— MS 32 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 2.94

f (Hz)	Level (g^2/Hz or dB/oct)
20-30	0.0030
30-50	-15.9
50-80	0.0002
80-100	43.3
100-160	0.0050
160-200	24.1
200-300	-22.2
300-600	13.0
600-1000	-27.0
1000-1200	31.2
1200-1600	0.0020
1600-2000	-31.0

••••••• MS 125 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 3.41

f (Hz)	Level (g^2/Hz or dB/oct)
20-30	6.5
30-50	-10.5
50-160	0.0020
160-200	21.6
200-250	-21.6
250-450	0.0020
450-600	24.0
600-650	-71.1
650-2000	3.2

Buffet

——— MS 32 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 1.82

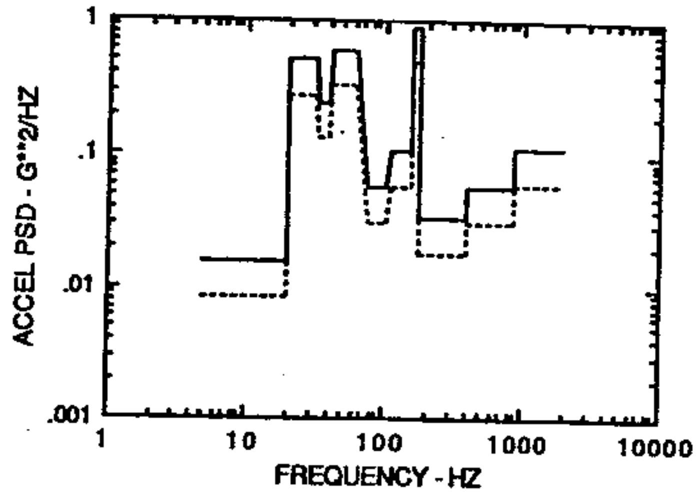
f (Hz)	Level (g^2/Hz or dB/oct)
20-30	4.1
30-60	-18.8
60-90	0.0009
90-100	48.8
100-170	0.0050
170-200	38.4
200-300	-24.3
300-400	0.0015
400-500	13.2

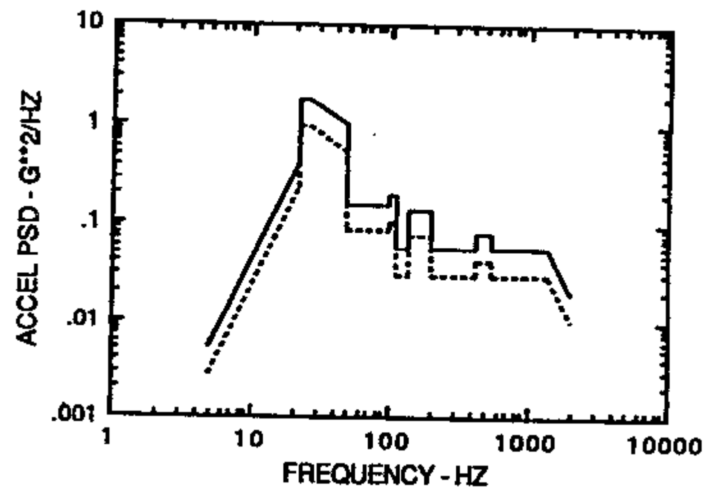
••••••• MS 125 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 2.44

f (Hz)	Level (g^2/Hz or dB/oct)
20-30	11.9
30-75	-19.6
75-125	0.0010
125-200	14.7
200-250	-18.6
250-350	0.0025
350-500	11.7

Note: Inertia relief is not applicable in Region 9D.

Figure 29
Region 10A - Wing Inboard Pylon Weapons Stations 2 and 8
Pylon Shoulder Stations 2A & 2B and 8A & 8B
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition

Vertical Axis

------- Performance - 0.5 hrs ——— Endurance - 2 hrs

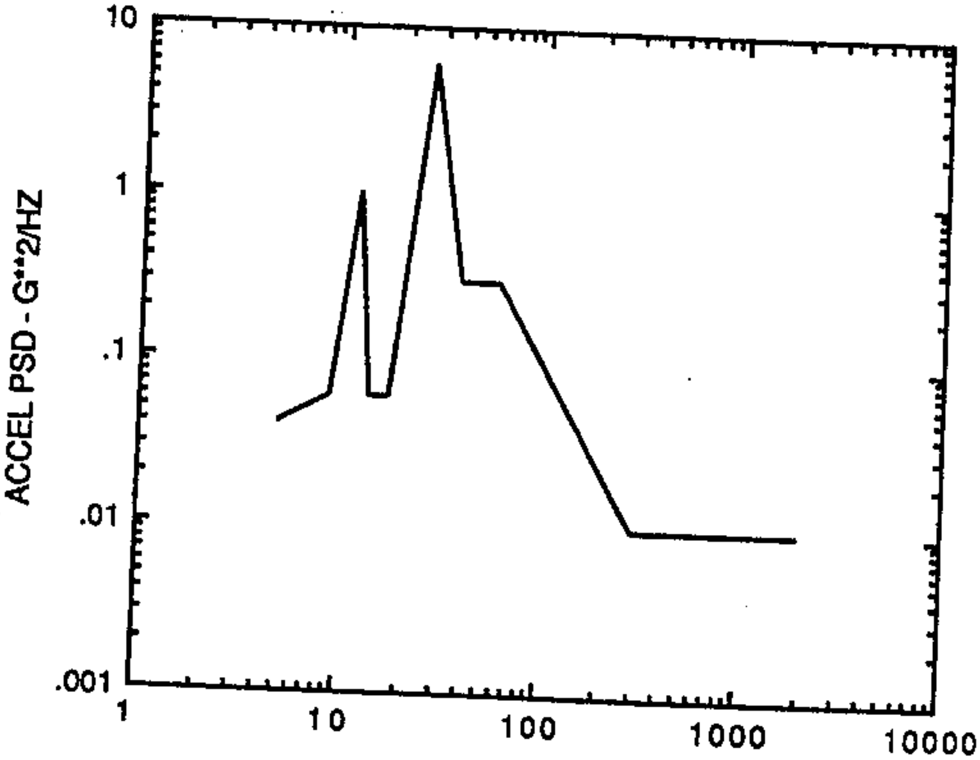
f (Hz)	Level (g^2/Hz or dB/oct) g_{rms} overall = 10.57	f (Hz)	Level (g^2/Hz or dB/oct) g_{rms} overall = 14.37
5-20	0.0083	5-20	0.015
20-32	0.272	20-32	0.503
32-34	-36.0	32-34	-36.0
34-39	0.132	34-39	0.243
39-42	36.0	39-42	36.0
42-63	0.319	42-63	0.590
63-77	-35.4	63-77	-35.4
77-105	0.030	77-105	0.055
105-112	29.3	105-112	29.3
112-160	0.056	112-160	0.104
160-180	0.477	160-180	0.883
180-400	0.018	180-400	0.033
400-900	0.030	400-900	0.055
900-2000	0.060	900-2000	0.111

Lateral and Longitudinal Axes

------- Performance - 0.5 hrs/axis ——— Endurance - 2 hrs/axis

f (Hz)	Level (g^2/Hz or dB/oct) g_{rms} overall = 8.92	f (Hz)	Level (g^2/Hz or dB/oct) g_{rms} overall = 12.13
5-22	9.0	5-22	9.0
22	0.225	22	0.415
22-26	0.952	22-26	1.761
26-50	-2.6	26-50	-2.6
50-100	0.083	50-100	0.154
100-115	0.102	100-115	0.188
115-140	0.029	115-140	0.053
140-200	0.073	140-200	0.135
200-425	0.029	200-425	0.053
425-550	0.042	425-550	0.078
550-1400	0.029	550-1400	0.053
1400-2000	-9.0	1400-2000	-9.0

Figure 30
Region 10B - AIM-9 Missile Wing Inboard Pylon Carriage Weapons Stations 2 and 8
Non-Gunfire Random Vibration Test Levels



Vibration Test Curve Definition

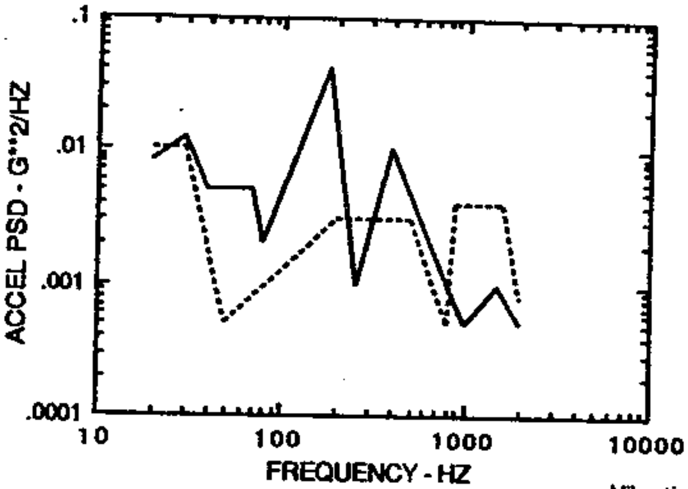
——— Seeker Performance
2 hrs/1000 flt hrs/axis; f ≤ 100 Hz
7 hrs/1000 flt hrs/axis; f ≥ 100 Hz

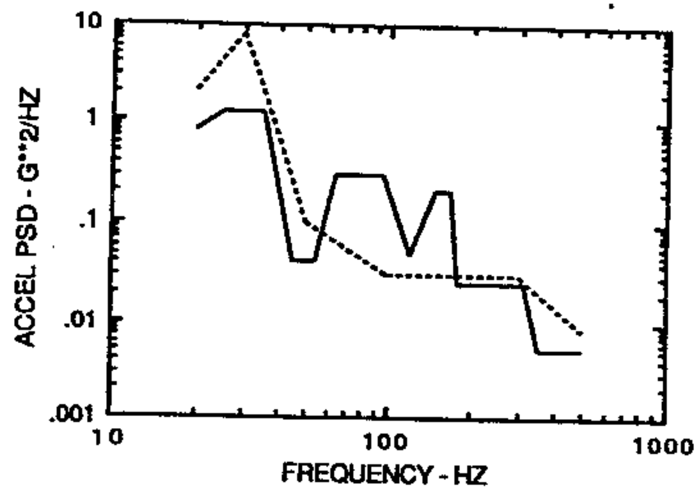
g_{rms} overall = 8.68

f (Hz)	Level (g^2/Hz or dB/oct)
5	0.040
5-9	2.1
9-12	29.3
12-14	-54.8
14-17	0.060
17-27	30.4
27-38	-27.0
38-60	0.300
60-300	-6.3
300-2000	0.010

Note: Inertia relief is not applicable in Region 10B.

Figure 31
Region 10C - AIM-120 Missile + LAU-128 Wing Inboard Pylon
Shoulder Carriage Weapons Stations 2A & 2B and 8A & 8B
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition

Non-Buffet

—— MS 32 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 2.33

f (Hz)	Level (g^2/Hz or dB/oct)
20-30	3.0
30-40	-9.1
40-70	0.0050
70-80	-20.6
80-180	11.1
180-250	-33.7
250-400	14.7
400-1000	-9.8
1000-1500	5.1
1500-2000	-7.2

-------- MS 125 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 2.33

f (Hz)	Level (g^2/Hz or dB/oct)
20-30	0.010
30-50	-17.6
50-200	3.9
200-500	0.0030
500-800	-11.4
800-900	53.0
900-1600	0.0040
1600-2000	-21.6

Buffet

—— MS 32 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 6.85

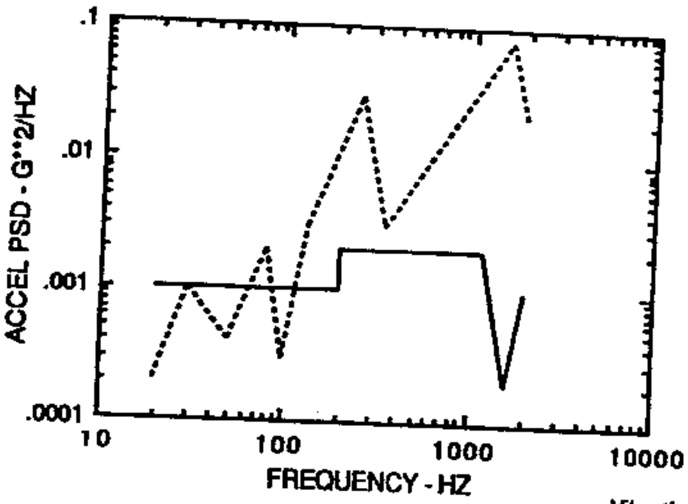
f (Hz)	Level (g^2/Hz or dB/oct)
20-25	5.5
25-35	1.20
35-45	-40.6
45-55	0.040
55-65	36.2
65-95	0.30
95-120	-23.0
120-150	18.6
150-170	0.20
170-180	-109.
180-310	0.025
310-350	-39.8
350-500	0.0050

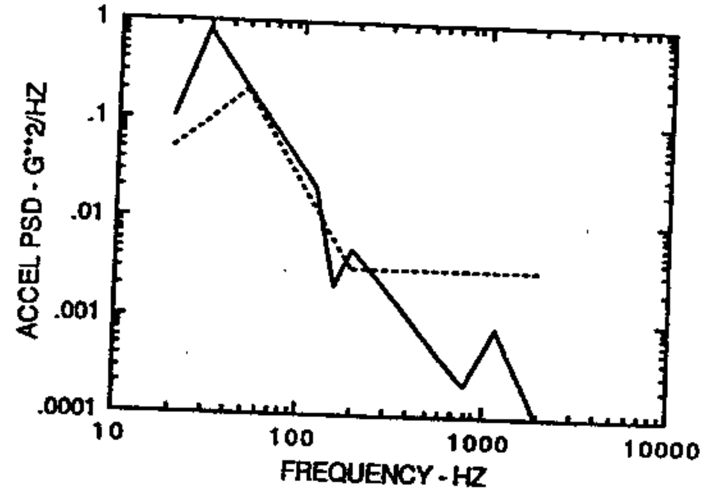
-------- MS 125 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 9.39

f (Hz)	Level (g^2/Hz or dB/oct)
20-30	10.3
30-50	-25.7
50-100	-5.2
100-300	0.030
300-500	-7.8

Note: Inertia relief is not applicable in Region 10C.

Figure 32
Region 10D - AGM-65 Missile + LAU-117 or LAU-88
Wing Inboard Pylon Carriage Weapons Stations 2 and 8
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition

Non-Buffet

——— Fwd Section Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 1.64

f (Hz)	Level (g^2/Hz or dB/oct)
20-200	0.0010
200-1200	0.0020
1200-1600	-24.0
1600-2000	21.6

-------- Aft Section Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 7.74

f (Hz)	Level (g^2/Hz or dB/oct)
20-30	11.9
30-50	-5.4
50-80	10.3
80-100	-25.5
100-130	26.3
130-250	10.6
250-350	-20.5
350-1600	6.5
1600-2000	-18.6

Buffet

——— Fwd Section Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 4.31

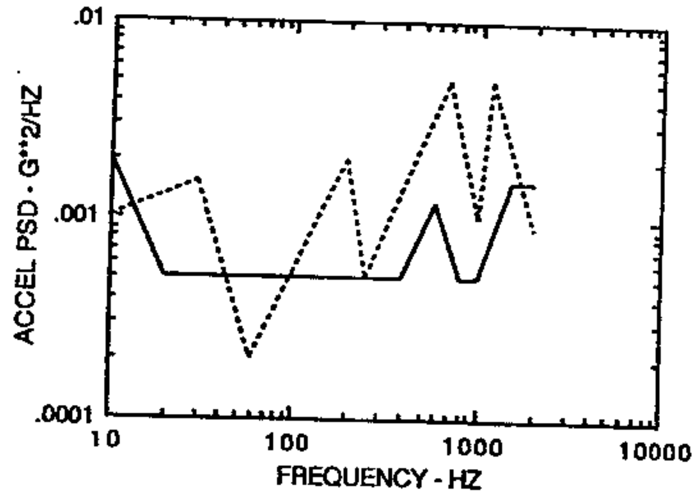
f (Hz)	Level (g^2/Hz or dB/oct)
20-30	15.4
30-125	-7.8
125-160	-28.0
160-200	12.3
200-800	-7.0
800-1200	10.3
1200-2000	-12.2

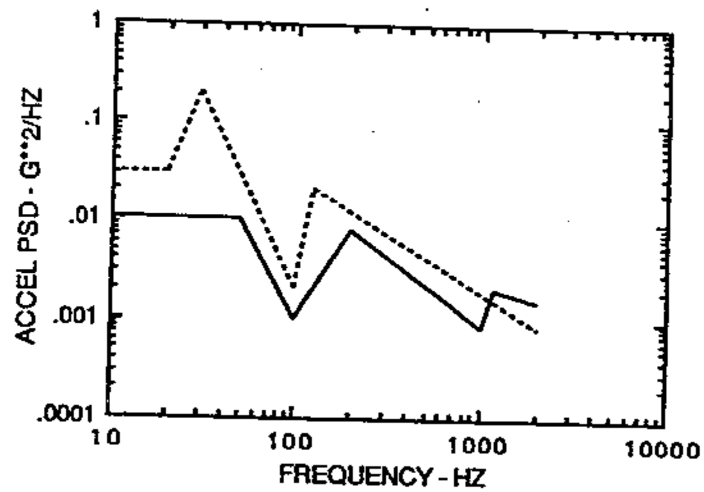
-------- Aft Section Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 3.69

f (Hz)	Level (g^2/Hz or dB/oct)
20-50	4.5
50-200	-9.1
200-2000	0.0030

Note: Inertia relief is not applicable in Region 10D.

Figure 33
Region 10E - GBU-15 Smart Bomb Wing Inboard Pylon Carriage Weapons Stations 2 and 8
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition

Non-Buffet

——— Fwd Section Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 1.36

f (Hz)	Level (g^2/Hz or dB/oct)
10-20	-6.0
20-400	0.0005
400-600	6.5
600-800	-9.1
800-1000	0.0005
1000-1500	8.1
1500-2000	0.0015

-------- Aft Section Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 2.05

f (Hz)	Level (g^2/Hz or dB/oct)
10-30	1.1
30-60	-8.7
60-200	5.7
200-250	-18.6
250-700	6.7
700-1000	-13.5
1000-1200	26.5
1200-2000	-10.8

Buffet

——— Fwd Section Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 2.11

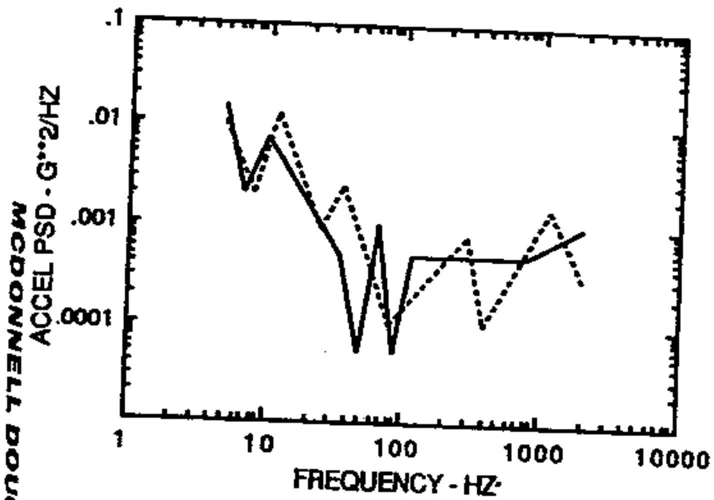
f (Hz)	Level (g^2/Hz or dB/oct)
10-50	0.010
50-100	-10.0
100-200	9.0
200-1000	-4.3
1000-1200	15.1
1200-2000	-1.7

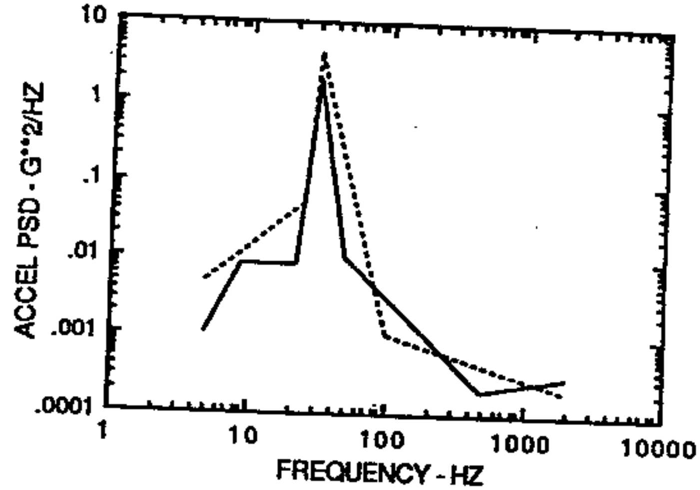
-------- Aft Section Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 3.02

f (Hz)	Level (g^2/Hz or dB/oct)
10-20	0.030
20-30	14.0
30-100	-11.5
100-125	31.0
125-2000	-3.5

Note: Inertia relief is not applicable in Region 10E.

Figure 34
Region 10F - SRAMT Missile + Multipurpose Adapter
Wing Inboard Pylon Carriage Weapons Stations 2 and 8
Non-Gunfire Random Vibration Test Levels





<u>Vibration Test Curves Definition</u>

Non-Buffet

——— MS 46 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 1.16

f (Hz)	Level (g^2/Hz or dB/oct)
5	0.015
5-7	-18.0
7-10	10.5
10	0.007
10-35	-6.3
35-50	-19.4
50	0.00005
50-65	34.3
65-90	-27.7
90-120	24.0
120-800	0.0005
800-2000	2.3

········ MS 152 Performance
7 hrs/axis/1000 flt hrs
g_{rms} overall = 1.15

f (Hz)	Level (g^2/Hz or dB/oct)
5	0.010
5-8	-10.3
8-12	13.3
12	0.012
12-25	-10.6
25-37	7.8
37	0.0025
37-80	-12.5
80-300	4.7
300	0.0008
300-400	-21.7
400-1200	7.4
1200	0.0015
1200-2000	-9.5

Buffet

——— MS 46 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 3.29

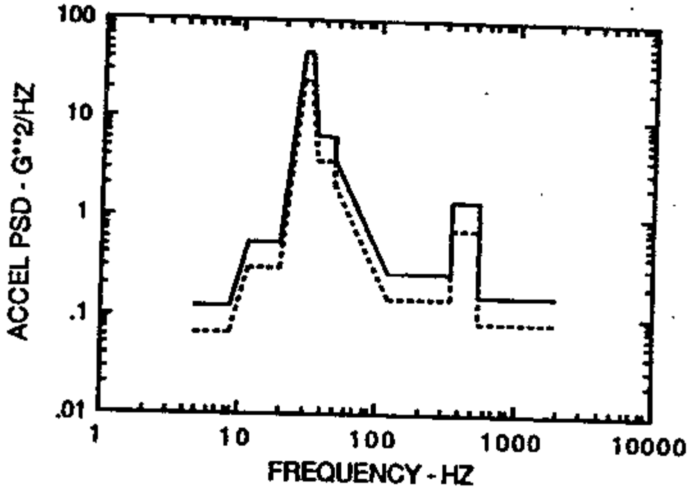
f (Hz)	Level (g^2/Hz or dB/oct)
5-9	10.6
9-22	0.008
22-31	48.3
31-50	-33.3
50	0.010
50-500	-5.1
500-2000	0.9

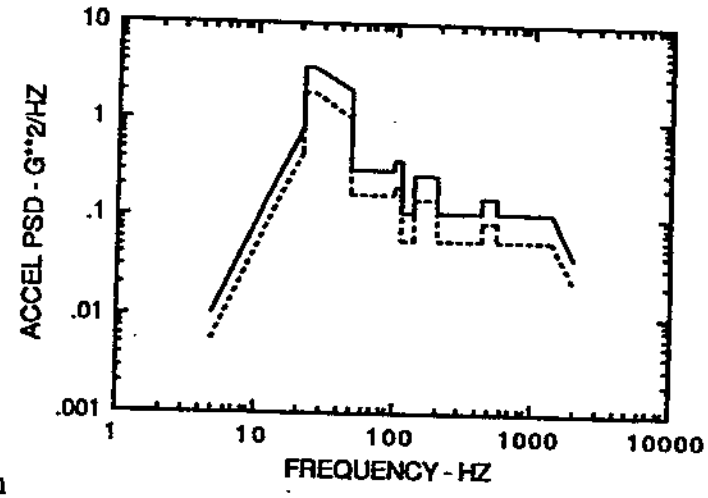
········ MS 152 Performance
2 hrs/axis/1000 flt hrs
g_{rms} overall = 5.22

f (Hz)	Level (g^2/Hz or dB/oct)
5	0.005
5-25	4.3
25-31	61.1
31-100	-21.2
100	0.001
100-2000	-1.6

Note: Inertia relief is not applicable in Region 10F.

Figure 35
Region 11A - Wing Outboard Pylon Weapons Stations 1 and 9
Non-Gunfire Random Vibration Test Levels





Vibration Test Curves Definition

Vertical Axis

.... Performance - 0.5 hrs ——— Endurance - 2 hrs

g_{rms} overall = 23.73		g_{rms} overall = 32.27	
f (Hz)	Level (g^2/Hz or dB/oct)	f (Hz)	Level (g^2/Hz or dB/oct)
5-9	0.062	5-9	0.115
9-12	16.0	9-12	16.0
12-20	0.287	12-20	0.531
20-29	36.0	20-29	36.0
29-32	24.44	29-32	45.20
32-36	-50.0	32-36	-50.0
36-50	3.455	36-50	6.390
50	2.075	50	3.838
50-123	-9.0	50-123	-9.0
123-355	0.139	123-355	0.257
355-563	0.716	355-563	1.323
563-2000	0.082	563-2000	0.151

Lateral and Longitudinal Axes

.... Performance - 0.5 hrs/axis ——— Endurance - 2 hrs/axis

g_{rms} overall = 12.47		g_{rms} overall = 16.96	
f (Hz)	Level (g^2/Hz or dB/oct)	f (Hz)	Level (g^2/Hz or dB/oct)
5-22	9.0	5-22	9.0
22	0.439	22	0.812
22-26	1.860	22-26	3.440
26-50	-2.6	26-50	-2.6
50-100	0.163	50-100	0.302
100-115	0.199	100-115	0.367
115-140	0.056	115-140	0.104
140-200	0.143	140-200	0.264
200-425	0.056	200-425	0.104
425-550	0.082	425-550	0.152
550-1400	0.056	550-1400	0.104
1400-2000	-9.0	1400-2000	-9.0

Figure 36
Gunfire Vibration Regions

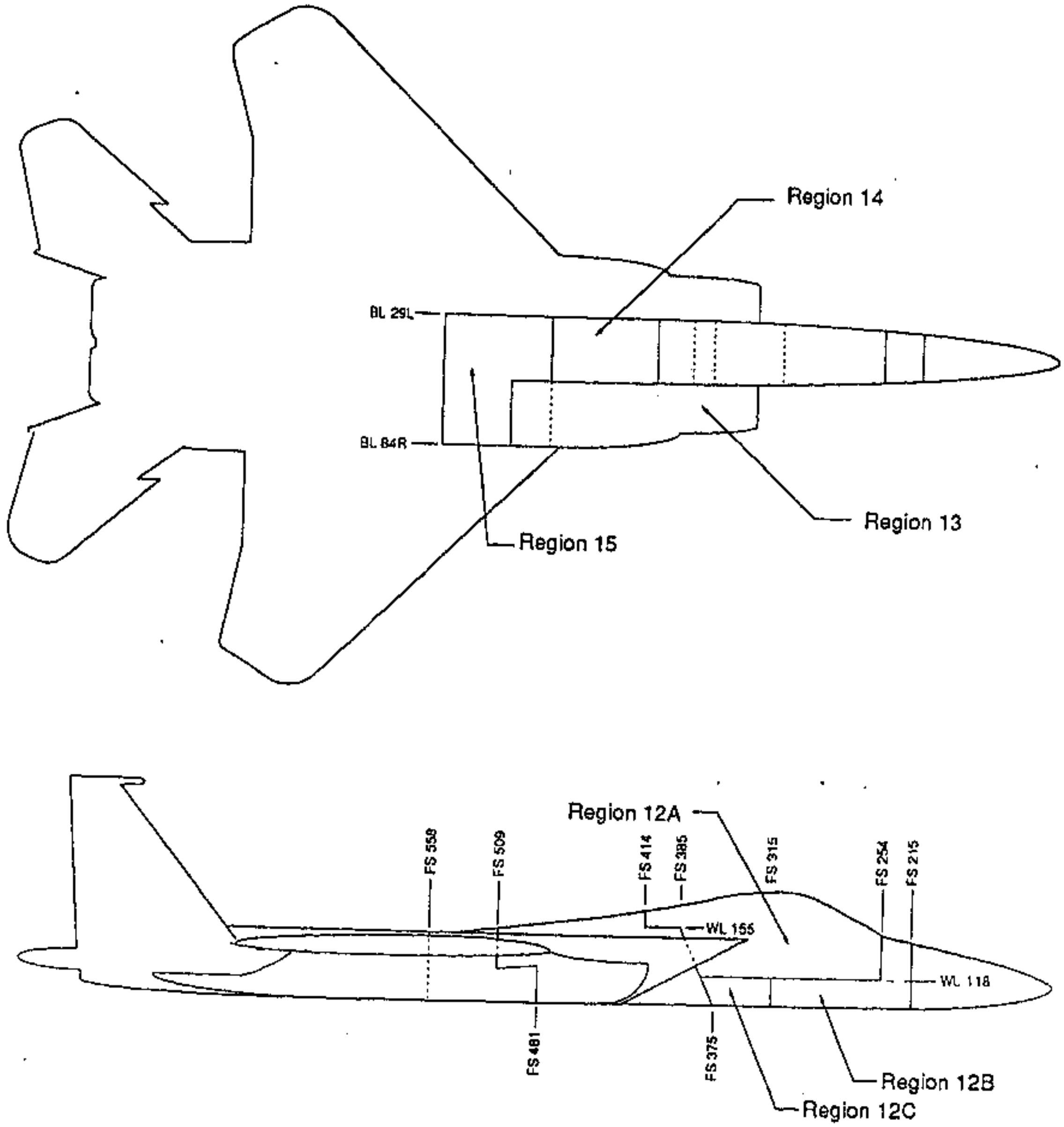
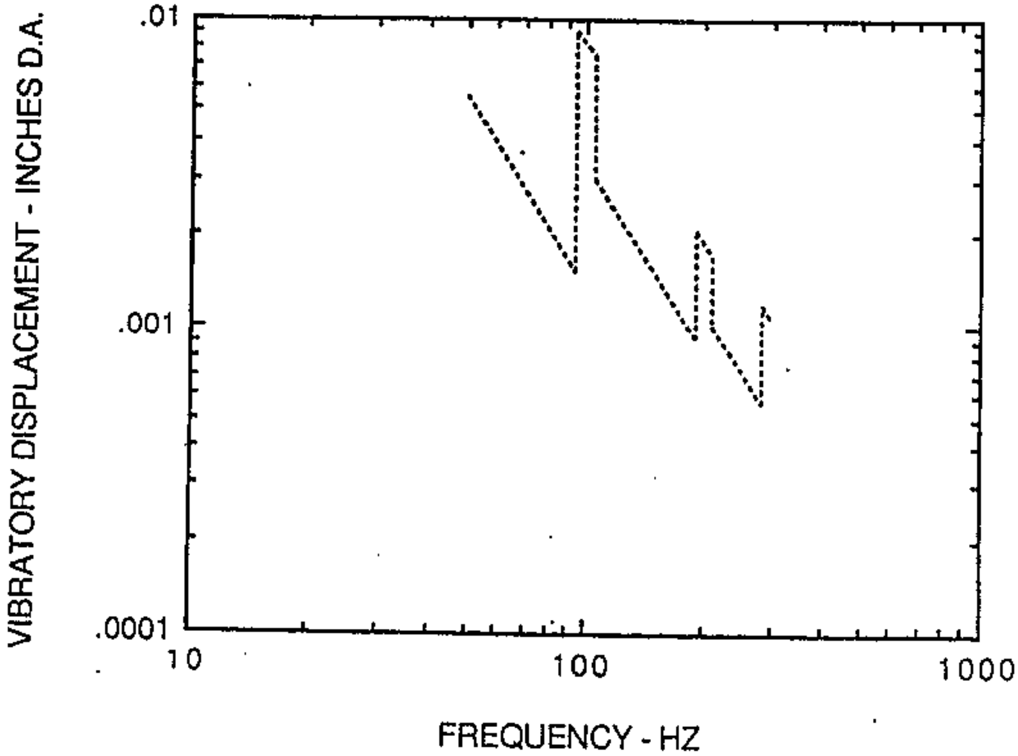


Figure 37
Region 12A - Crew Station*
Gunfire Sinusoidal Vibration Test Levels



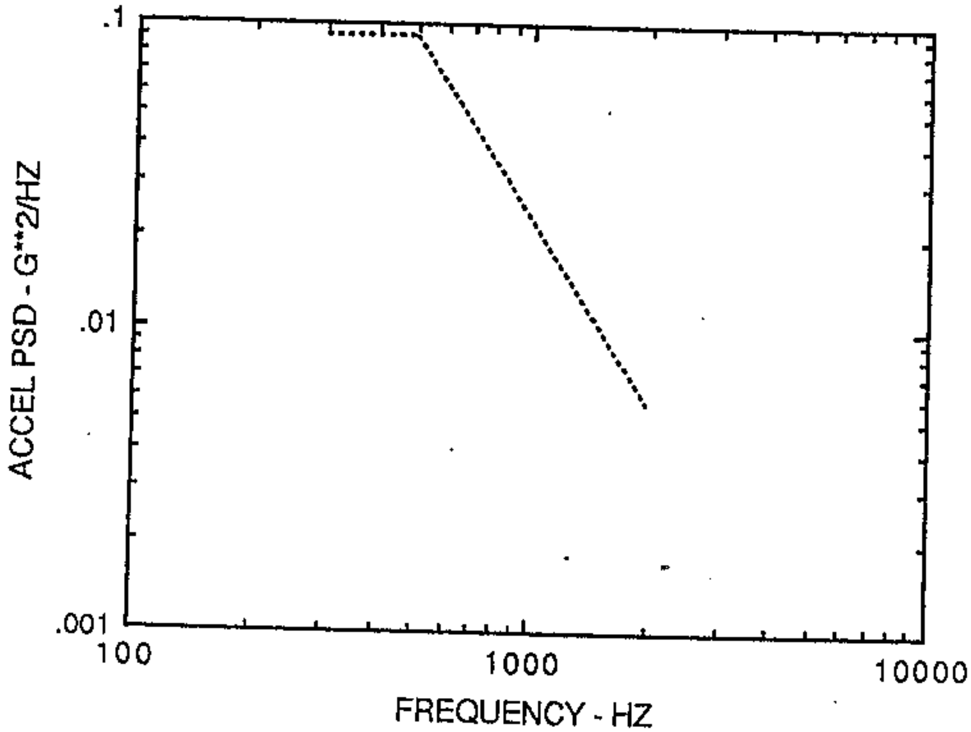
Vibration Test Curve Definition

.... Performance

f (Hz)	Level (g's)
50-95	±0.7
95-105	±4.2
105-190	±1.7
190-210	±3.8
210-285	±2.3
285-300	±4.9

*See Figure 49 for description of test duration.

Figure 38
Region 12A - Crew Station
Gunfire Random Vibration Test Levels



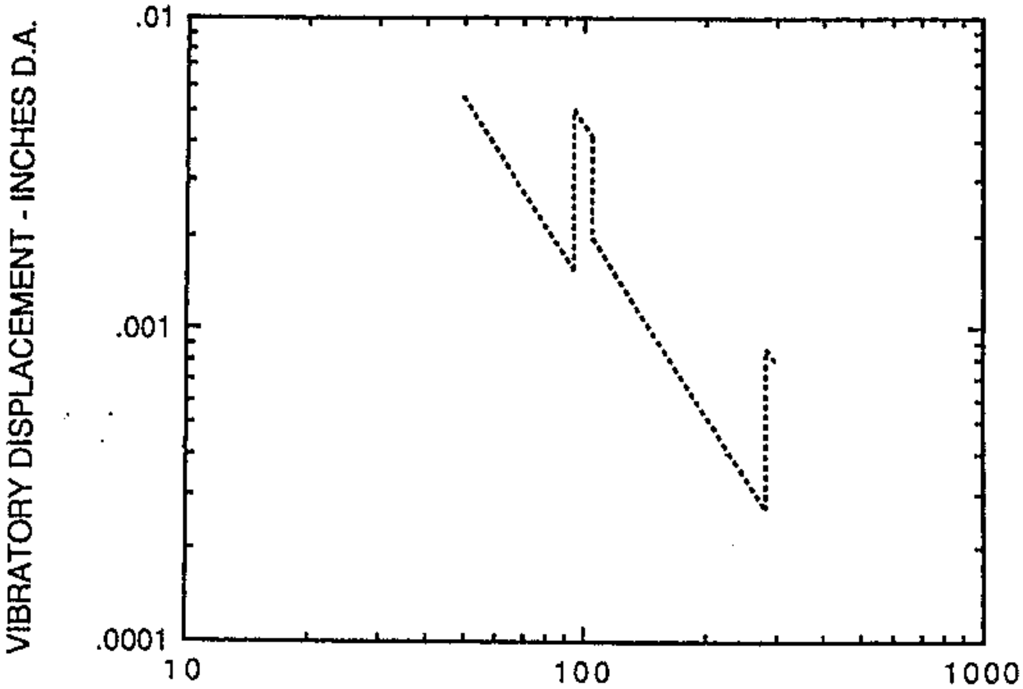
Vibration Test Curve Definition

.... Performance - 10 minutes/axis

g_{rms} overall = 7.20

f (Hz)	Level (g^2/Hz or dB/oct)
300-500	0.090
500-2000	-6.0

Figure 39
Region 12B - Forward Avionics Equipment Bay*
Gunfire Sinusoidal Vibration Test Levels



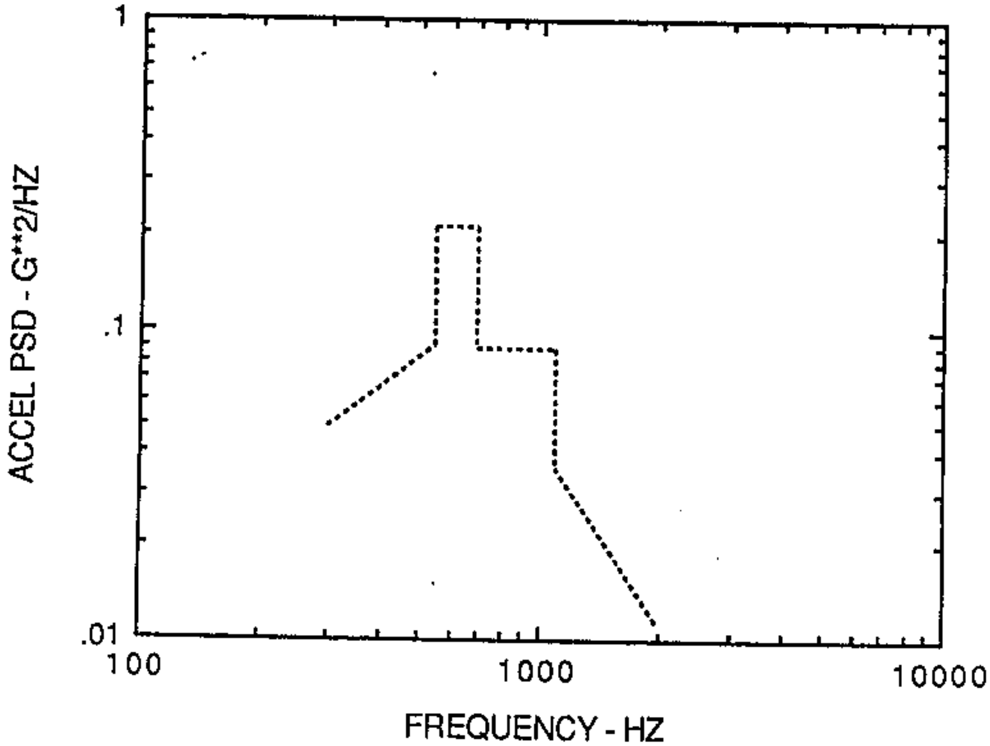
Vibration Test Curve Definition

.... Performance

f (Hz)	Level (g's)
50-95	±0.7
95-105	±2.3
105-285	±1.1
285-300	±3.6

*See Figure 49 for description of test duration.

Figure 40
Region 12B - Forward Avionics Equipment Bay
Gunfire Random Vibration Test Levels



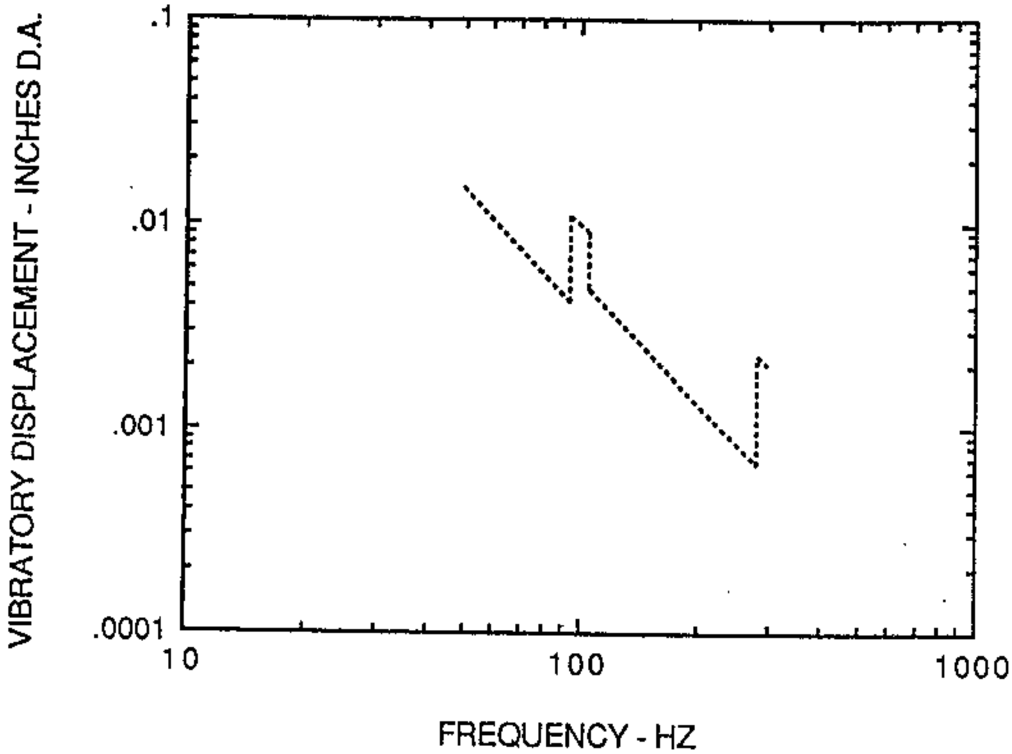
Vibration Test Curve Definition

•••••••• Performance - 10 minutes/axis

g_{rms} overall = 10.07

f (Hz)	Level (g^2/Hz or dB/oct)
300	0.049
300-550	3.0
550-700	0.210
700-1100	0.087
1100	0.036
1100-2000	-6.0

Figure 41
Region 12C - Aft Avionics Equipment Bay*
Gunfire Sinusoidal Vibration Test Levels



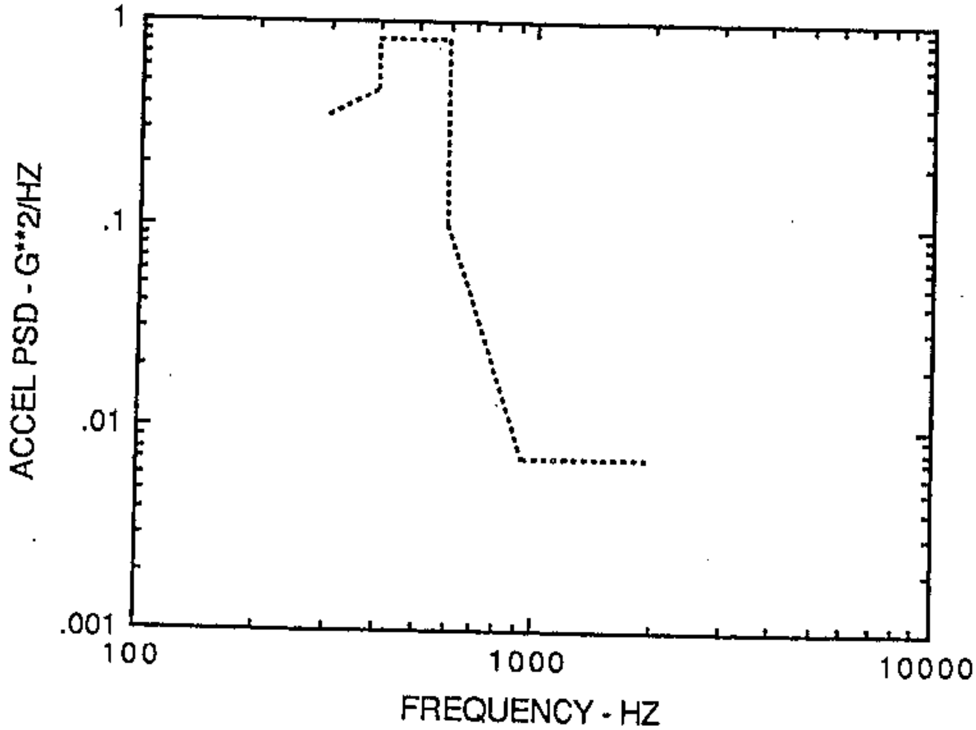
Vibration Test Curve Definition

•••••••• Performance

f (Hz)	Level (g's)
50-95	±1.9
95-105	±5.0
105-285	±2.7
285-300	±9.5

*See Figure 49 for description of test duration.

Figure 42
Region 12C - Aft Avionics Equipment Bay
Gunfire Random Vibration Test Levels



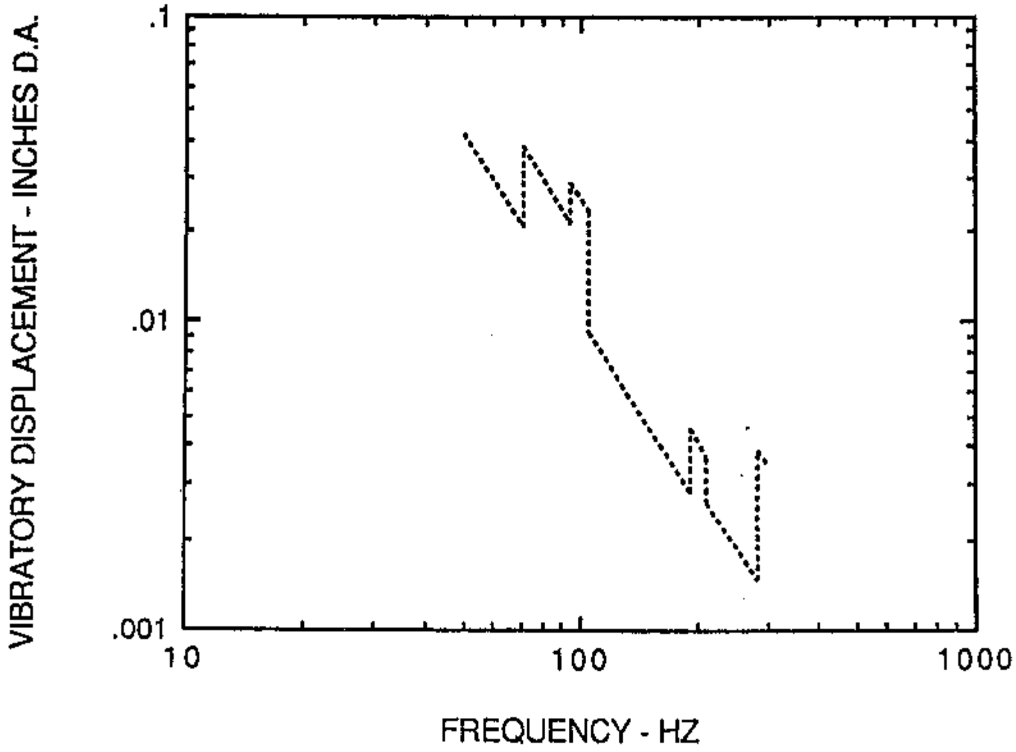
Vibration Test Curve Definition

.... Performance - 10 minutes/axis

g_{rms} overall = 14.75

f (Hz)	Level (g^2/Hz or dB/oct)
300	0.340
300-400	3.0
400-600	0.800
600	0.100
600-936	-18.0
936-2000	0.0070

Figure 43
Region 13 - Gun Bay/Muzzle Area*
Gunfire Sinusoidal Vibration Test Levels



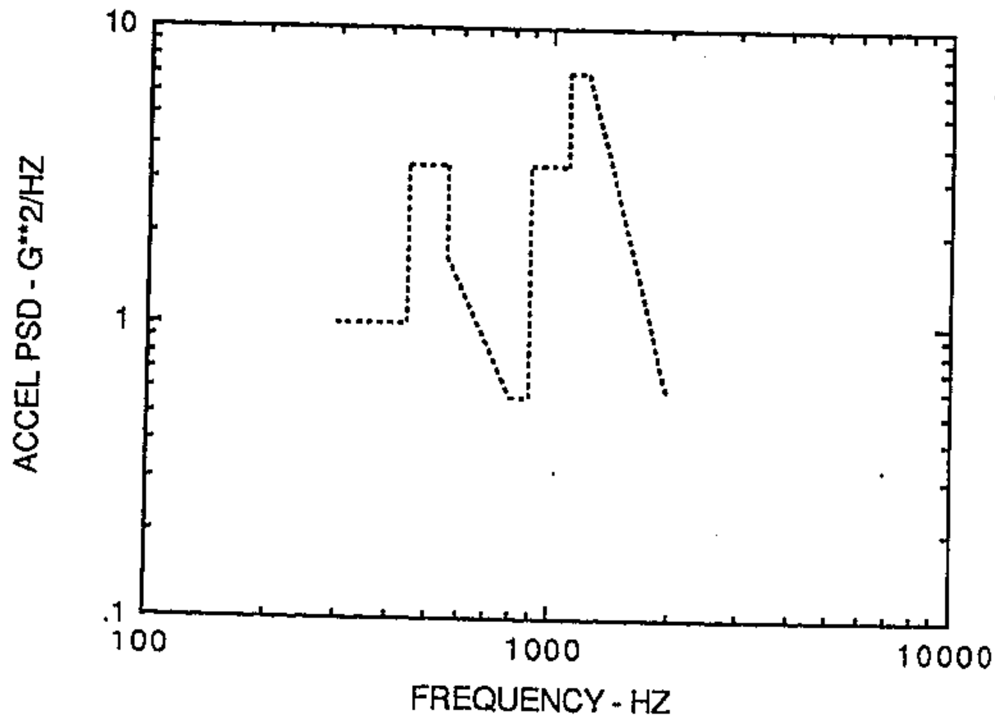
Vibration Test Curve Definition

.... Performance

f (Hz)	Level (g's)
50-71	±5.3
71-95	±9.7
95-105	±13.1
105-190	±5.2
190-210	±8.3
210-285	±6.0
285-300	±15.9

*See Figure 49 for description of test duration.

Figure 44
Region 13 - Gun Bay/Muzzle Area
Gunfire Random Vibration Test Levels



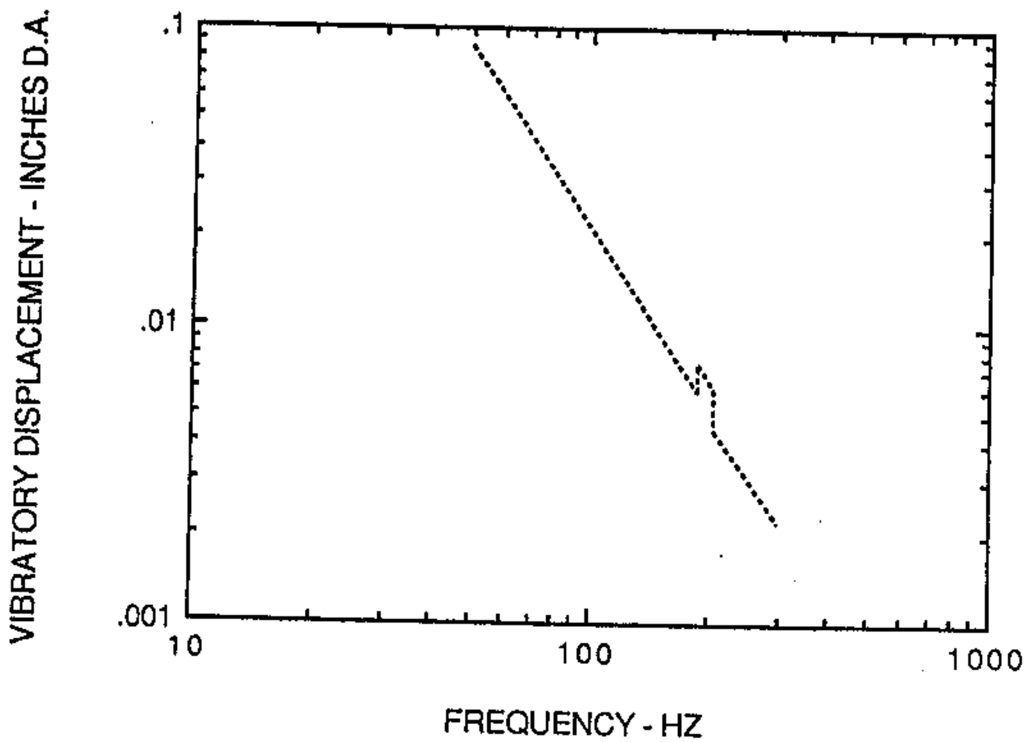
Vibration Test Curve Definition

.... Performance - 10 minutes/axis

g_{rms} overall = 65.10

f (Hz)	Level (g^2/Hz or dB/oct)
300-450	1.000
450-560	3.320
560	1.656
560-800	-9.0
800-890	0.570
890-1120	3.320
1120-1250	7.000
1250-2000	-16.0

Figure 45
Region 14 - Forward Center Fuselage*
Gunfire Sinusoidal Vibration Test Levels



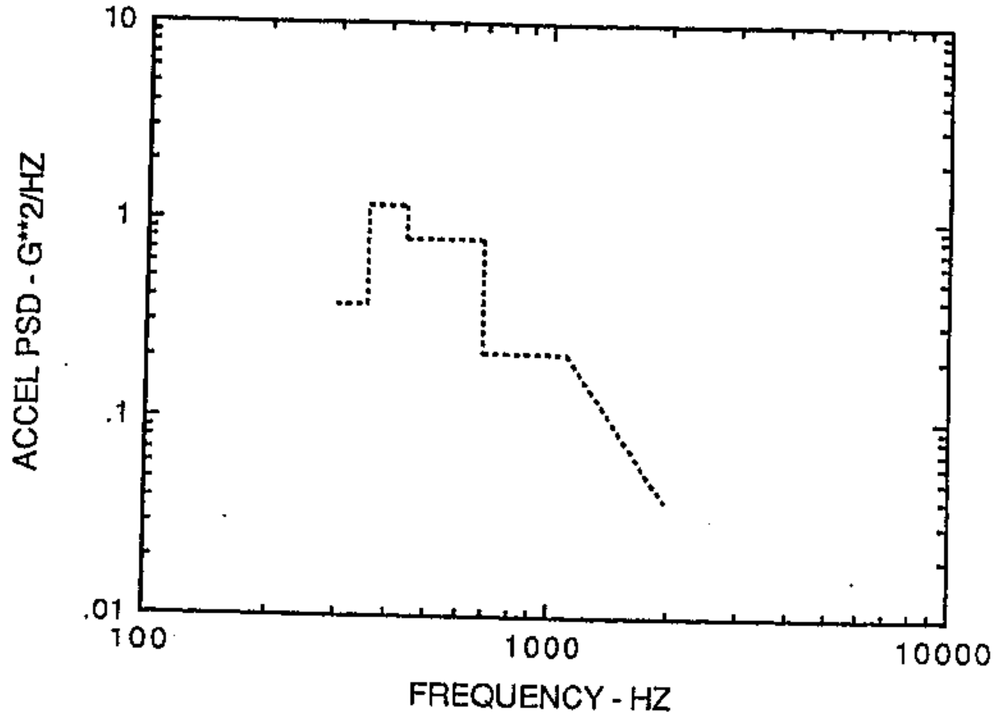
Vibration Test Curve Definition

.... Performance

f (Hz)	Level (g's)
50-190	±11.0
190-210	±13.6
210-300	±10.0

*See Figure 49 for description of test duration.

Figure 46
Region 14 - Forward Center Fuselage
Gunfire Random Vibration Test Levels



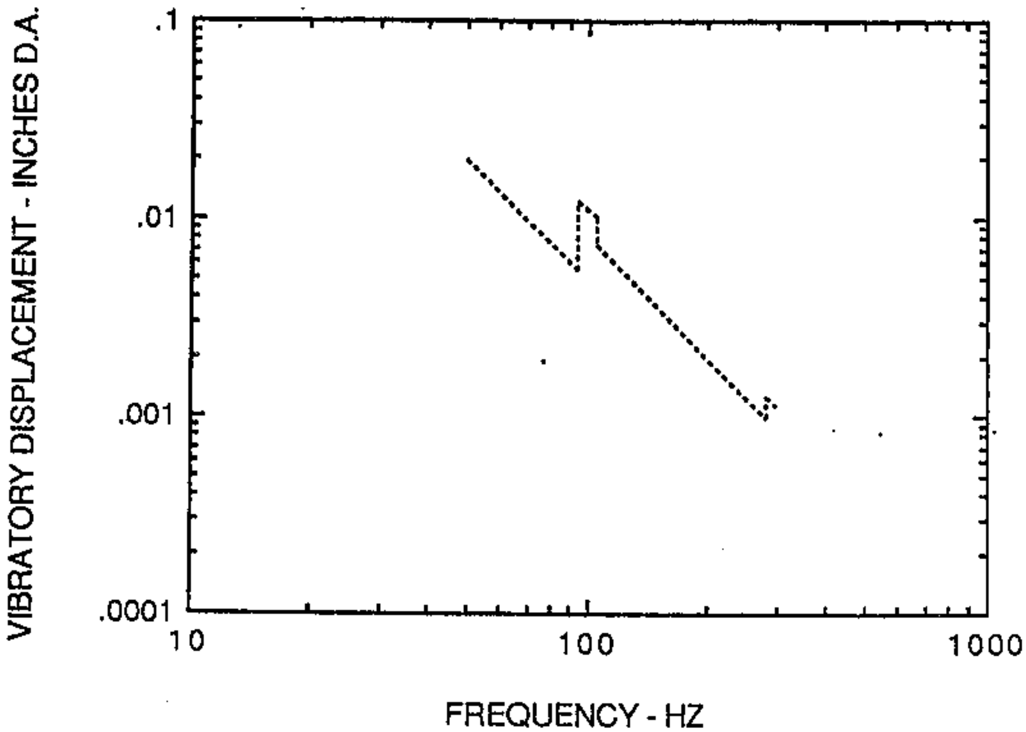
Vibration Test Curve Definition

•••••••• Performance - 10 minutes/axis

g_{rms} overall = 22.16

f (Hz)	Level (g^2/Hz or dB/oct)
300-360	0.355
360-450	1.167
450-700	0.780
700-1120	0.211
1120-2000	-9.0

Figure 47
Region 15 - Aft Center Fuselage*
Gunfire Sinusoidal Vibration Test Levels



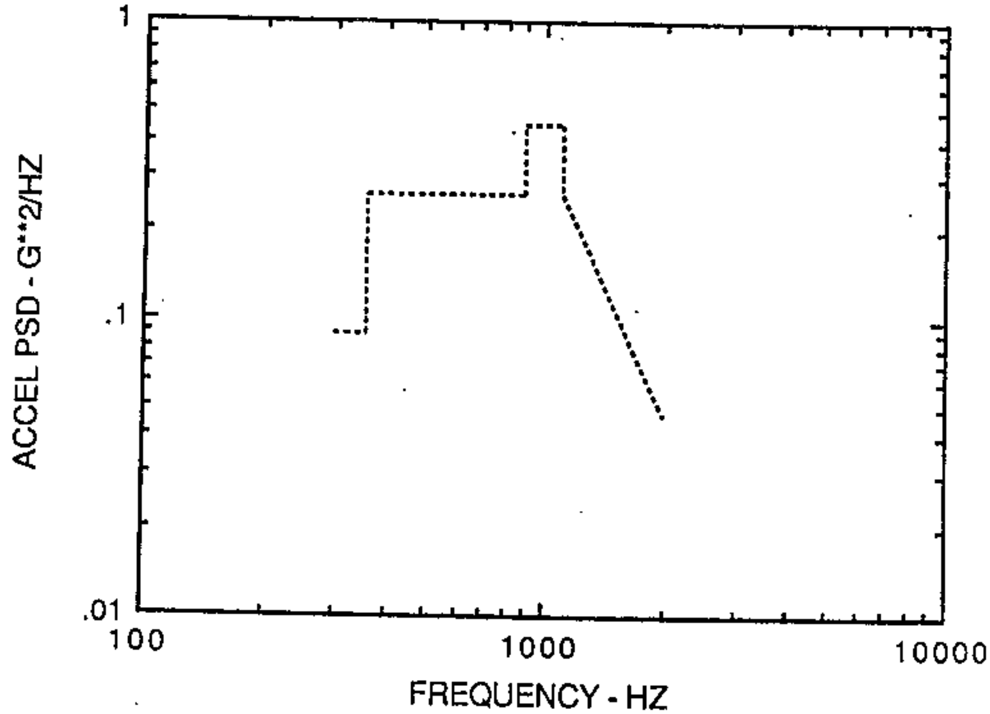
Vibration Test Curve Definition

.... Performance

f (Hz)	Level (g's)
50-95	±2.5
95-105	±5.6
105-285	±4.0
285-300	±5.2

*See Figure 49 for description of test duration.

Figure 48
Region 15 - Aft Center Fuselage
Gunfire Random Vibration Test Levels



Vibration Test Curve Definition

.... Performance - 10 minutes/axis

g_{rms} overall = 18.65

f (Hz)	Level (g^2/Hz or dB/oct)
300-360	0.088
360-890	0.260
890-1120	0.450
1120	0.263
1120-2000	-9.0

Figure 49
Gunfire Sinusoidal Vibration Test Schedule

Number of Resonances	0	1	2	3
50-300 Hz Cycling Time	15	10	5	0
Resonance Dwell Time	0	5	10	15
Fixed Narrow Band Dwells				
center frequency = 67 Hz	10	10	10	10
100 Hz	10	10	10	10
135 Hz	10	10	10	10
200 Hz	20.	20	20	20
267 Hz	10	10	10	10
300 Hz	10	10	10	10
Total Time per Axis	85	85	85	85

All test times are per axis in minutes.

NOTES:

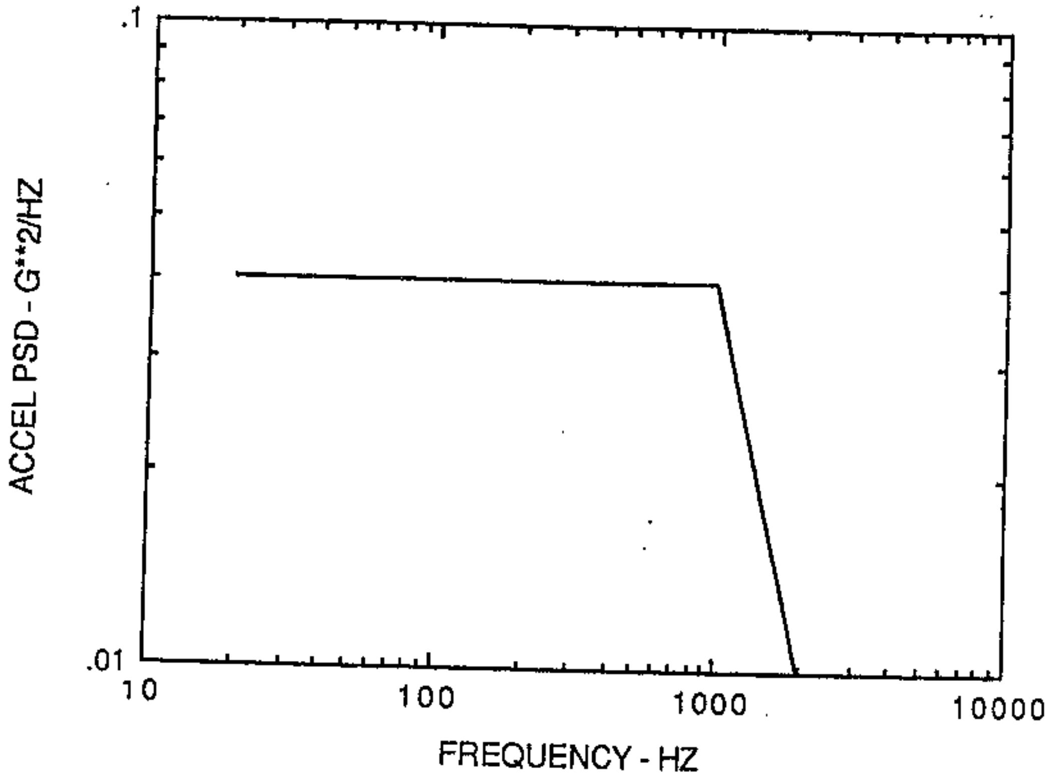
1. The fixed narrow band dwells shall be performed by sweeping the frequency about ±5% of the specified center frequency. For example, the 100 Hz dwell should be performed by sweeping from 95 Hz to 105 Hz and back to 95Hz for 10 minutes.

2. The sweep rate for both the 50-300 Hz cycling and the fixed narrow band dwells should be approximately 0.517 octaves/minute.

3. When an equipment resonance occurs within ±5% of a fixed narrow band dwell center frequency, the fixed narrow band dwell period shall be omitted and only the resonance dwell performed. The omitted fixed dwell time shall then be added to the sweep time.

4. If performance during gunfire is required, the performance shall be continuously monitored and results recorded during the sweep period, and and a performance check shall be made and results recorded during each fixed narrow band dwell or resonance dwell point.

Figure 50
Minimum Structural Integrity
Random Vibration Test Levels



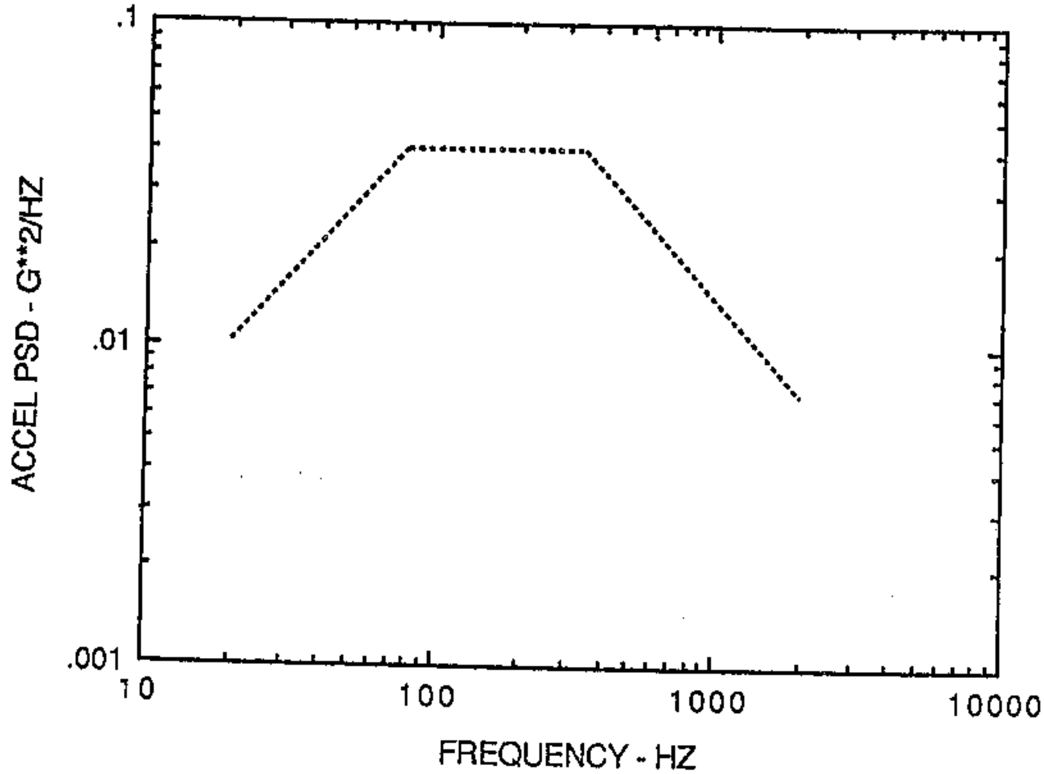
Vibration Test Curve Definition

—— Endurance - 1 hour/axis

g_{rms} overall = 7.70

f (Hz)	Level (g^2/Hz or dB/oct)
20-1000	0.040
1000-2000	-6.0

Figure 51
Environmental Stress Screening
Random Vibration Test Levels



Vibration Test Curve Definition

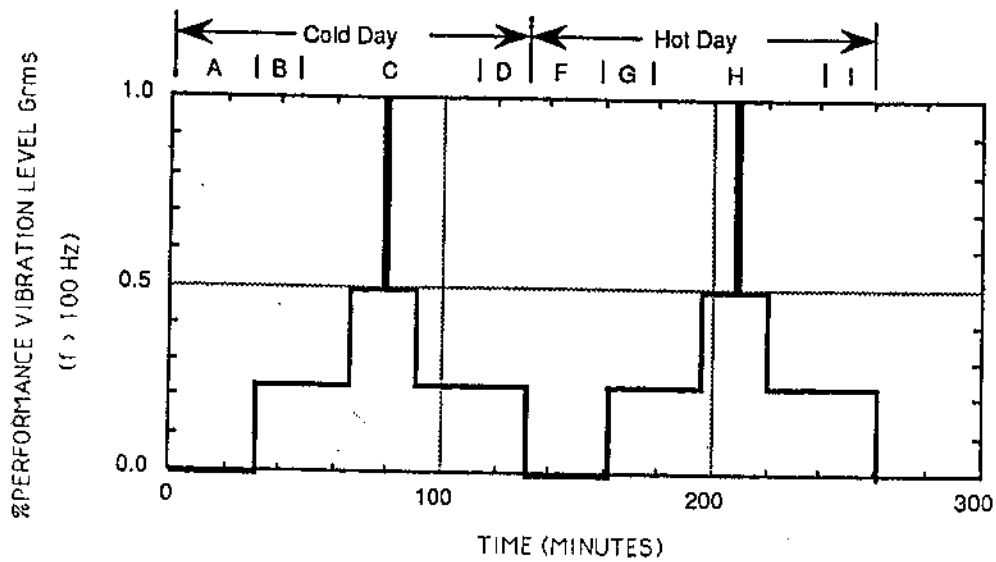
.... Performance - 10 minutes in each of two orthogonal axes*

g_{rms} overall = 6.06

f (Hz)	Level (g^2/Hz or dB/oct)
20-80	3.0
80-350	0.040
350-2000	-3.0

* One axis shall be normal to the installation plane of the majority of circuit boards.

Figure 52
Reliability Development Test
Vibration Mission Profile Cycle
Based on Overall F-15E Fleet Usage Through 1991



Mission Phase
A,F: Ground Operation
B,G: Take-off, Climb to Altitude
C,H: Mission Objective
D,I: Descent, Landing
E,J: Ground Non-operating (Equipment Dependent)

Time Interval (Minutes)	Percentage of Performance Nongunfire Vibration Level Grms (f > 100 Hz)
30	0
35	24
12	50
0.42	100
11.58	50
41	24
30	0
35	24
12	50
0.42	100
11.58	50
41	24

The units shall be exposed to 26 seconds of 100% performance vibration level ($f \leq 100$ Hz) just prior to exposure to the 100% levels ($f \geq 100$ Hz) during mission phases C, H. The total number of (B-C-D) and (G-H-I) cycles is 924. The units shall also be subjected to gunfire vibration for one half of the time presented in Figure 49 (50-300 Hz sinusoidal vibration) and 5 minutes of gunfire random vibration (300-2000 Hz).

To simulate an entire lifetime of vibration on one of the two RDT units, one unit shall be exposed to 6.4 hrs of nongunfire vibration at 100% performance level ($f \leq 100$ Hz) and 21 hrs at 100% performance level ($f \geq 100$ Hz) prior to the actual RDT test. This unit shall also be subjected to gunfire vibration for one half of the time presented in Figure 49 (50-300 Hz sinusoidal vibration) and 5 minutes of gunfire random vibration (300-2000 Hz) prior to the actual RDT test.

Figure 53
Avionics Integrity Program (AVIP)
Flight Vibration Exposure Requirements [1]
Based on Overall F-15E Fleet Usage Through 1991

Non-Buffet Flight Condition Usage
(Random Vibration Above 100 Hz)

Level*	Exposure Time (hrs)
100%	0.23
90%	1.7
74%	4.0
64%	62.
55%	372.
46%	947.
36%	1468.
24%	2536.
16%	1235.
7%	485.

Buffet Flight Condition Usage
(Random Vibration Below 100 Hz)

Level*	Exposure Time (hrs)
100%	1.6
90%	3.2
80%	3.6
70%	17.
60%	12.
50%	15.
40%	17.
30%	20.
20%	48.
10%	569.

Gunfire Flight Condition Usage
(Sinusoidal Vibration 50-300 Hz and Random Vibration 300-3000 Hz)

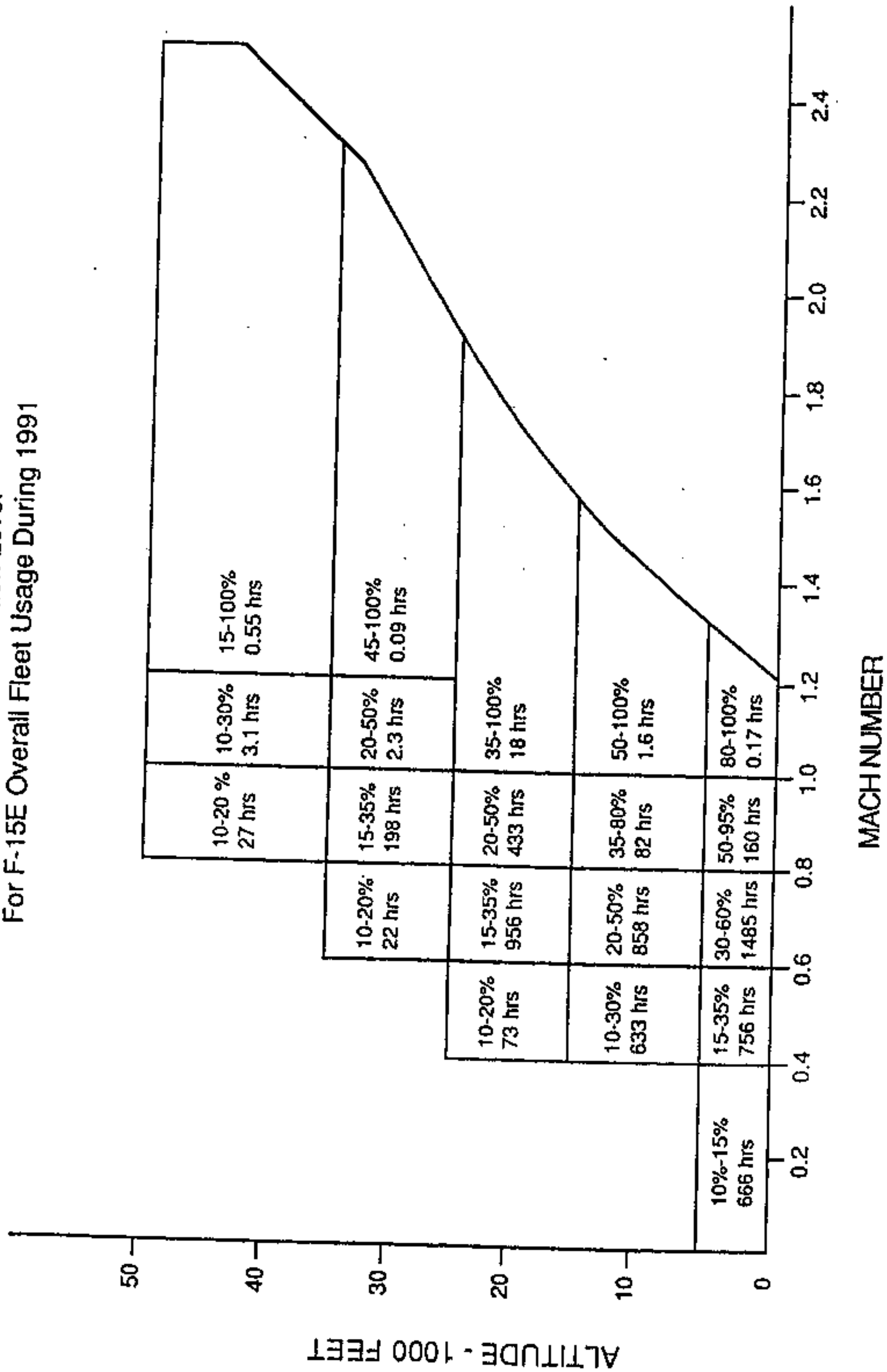
Level*	Exposure Time (min)
100%	10. [2]

1: For additional information, please contact the F-15 SPO or MCAIR.

2: See Figure 49 for 50-300 Hz sinusoidal vibration exposure schedule.

* Percent of performance vibration level in Grms (random) or peak g's (sinusoidal)

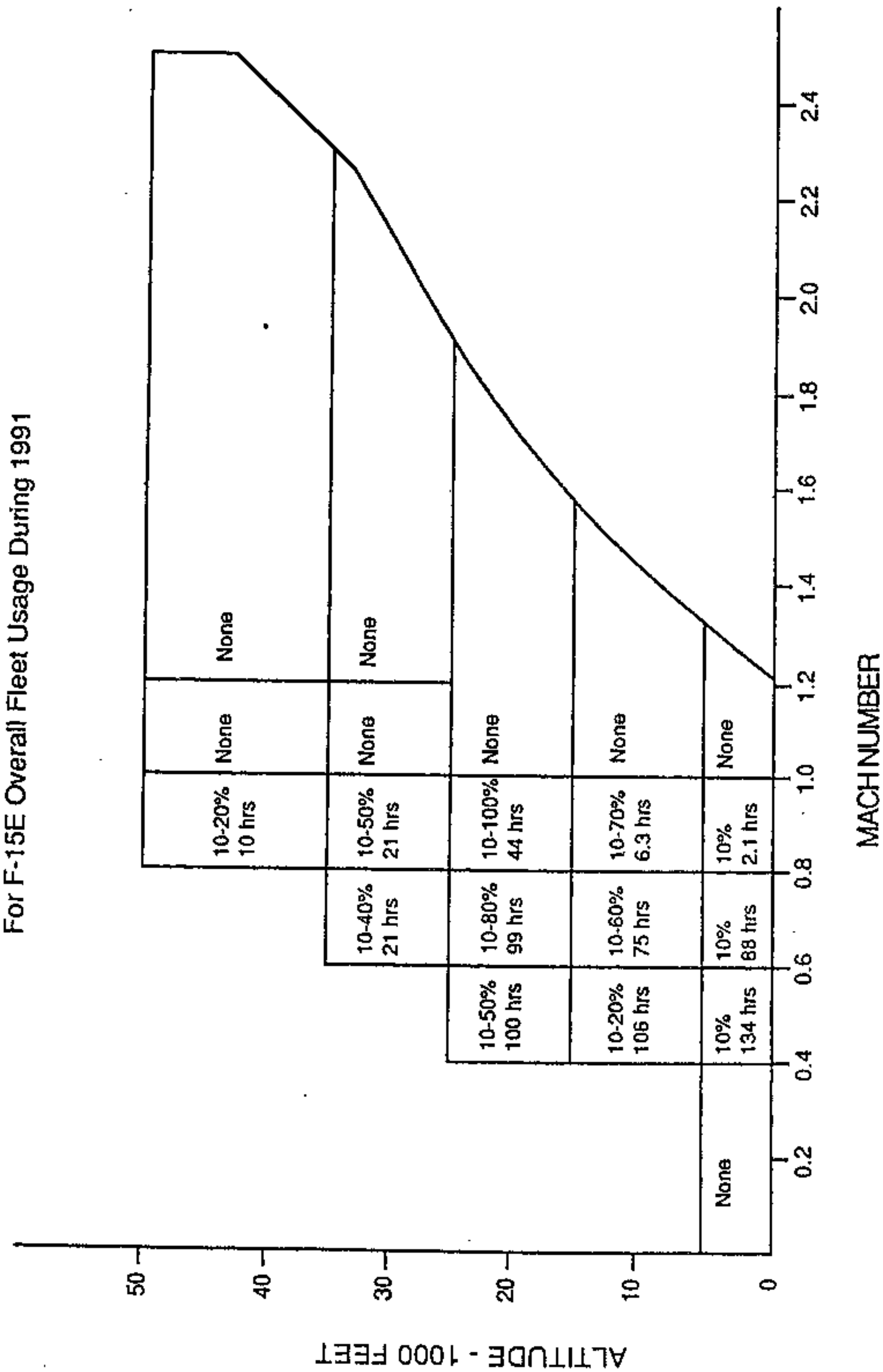
Figure 54
F-15E Non-buffet Usage Information
Mach/Altitude/Vibration Level
For F-15E Overall Fleet Usage During 1991



All percentages shown above are % of maximum performance vibration level Grms for frequencies $\geq$ 100 Hz.

All times are per 8000 flight log hours.

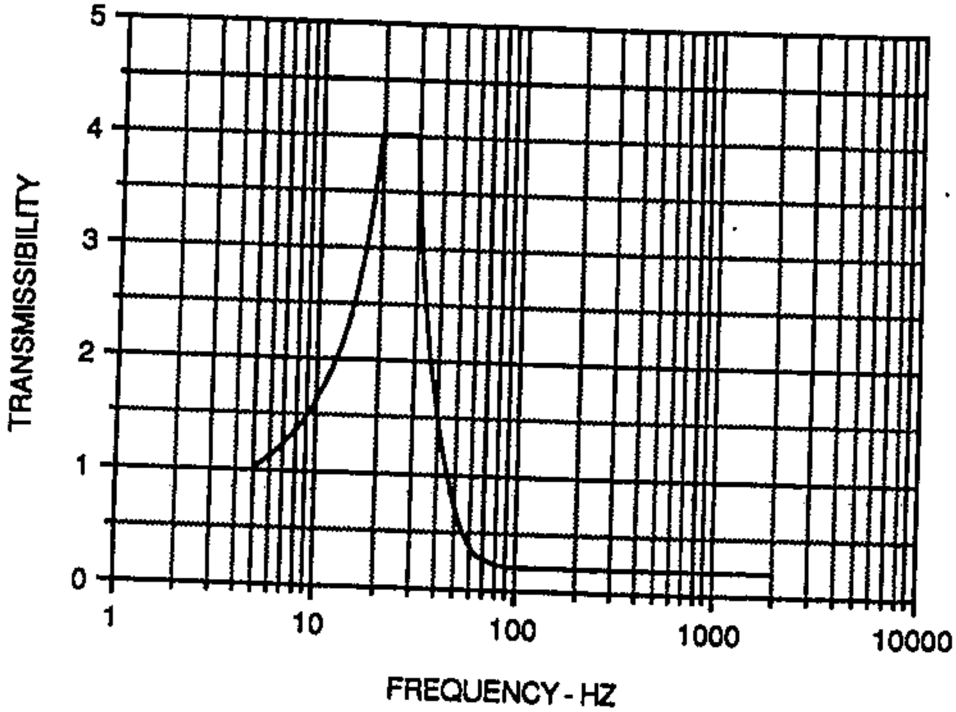
Figure 55
F-15E Buffet Usage Information
Mach/Altitude/Vibration Level
For F-15E Overall Fleet Usage During 1991



All percentages shown above are % of maximum performance vibration level Grms for frequencies $\leq$ 100 Hz.

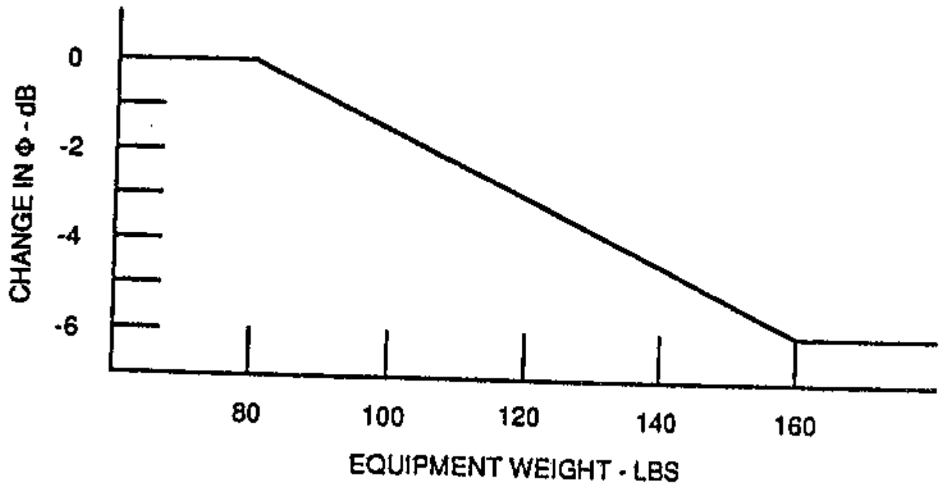
All times are per 8000 flight log hours.

Figure 56
Transmissibility of Resiliently Mounted Shelf or Panel



The transmissibility curve, ratio of output to input for the required resilient mounting system, should be used to modify the applicable endurance and performance test levels for equipment normally mounted to arrive at the test levels for equipment removed from the resiliently mounted shelf or panel. The transmissibility ratio applies to overall grms levels.

Figure 57
Random Vibration Inertia Relief



$$dB = 10 \, Log_{10} \left[\frac{\Phi^*}{\Phi} \right]$$

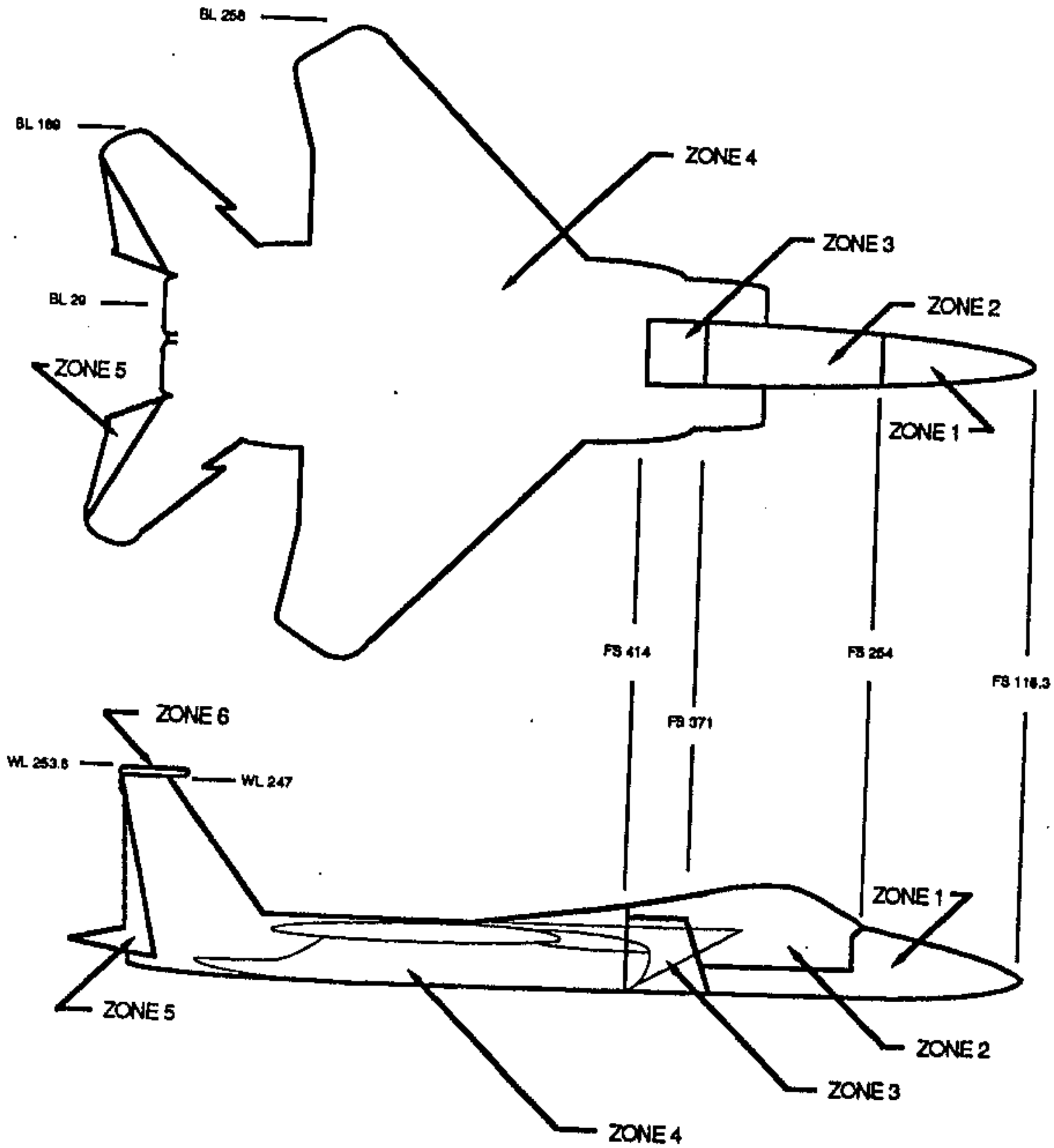
Φ^* is the reduced test level in g^2/Hz

$$dB = 20 \, Log_{10} \left[\frac{Overall \; g^*_{rms}}{Overall \; g_{rms}} \right]$$

Overall g^*_{rms} is the reduced test level

Note: This adjustment applies at frequencies above 30 Hz or as indicated in the individual equipment specification

Figure 58
Non-Gunfire Acoustic Noise Zones



ZONE 7 EXTERNAL EQUIPMENT

Figure 59
Overall Acoustic Noise Levels
And Frequency Spectrum (Non-Gunfire)

Zone	Description	Overall SPL (dB) Endurance 2 hours	Overall SPL (dB) Performance 30 minutes
1	Radar and Equipment Bays	130	126
2	Cockpit	128	124
3	ECS Bay	146	142
4	Wing, Aft and Center Fuselage, JFS Bay, and Empennage	150	146
5	Trailing Edges of Stabilators and Vertical Tails and Aft Boom	161	157
6	Vertical Tail Tip Pod	154	150
	External Equipment:		
7A	Lifting Surfaces	170	167
7B	Fwd Fuselage (Fwd of FS 340)	169	165
7C	Aft Fuselage (Aft of FS 340) or Behind Flow Obstructions	173	169

Non-Gunfire Acoustic Noise Frequency Spectrum

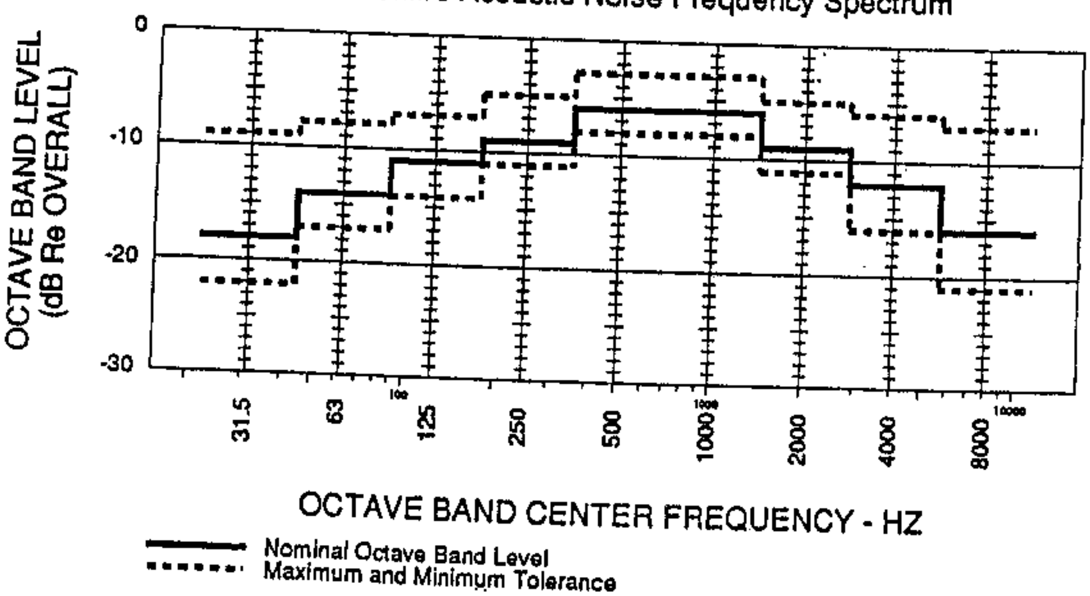


Figure 60
Gunfire Acoustic Noise Zones

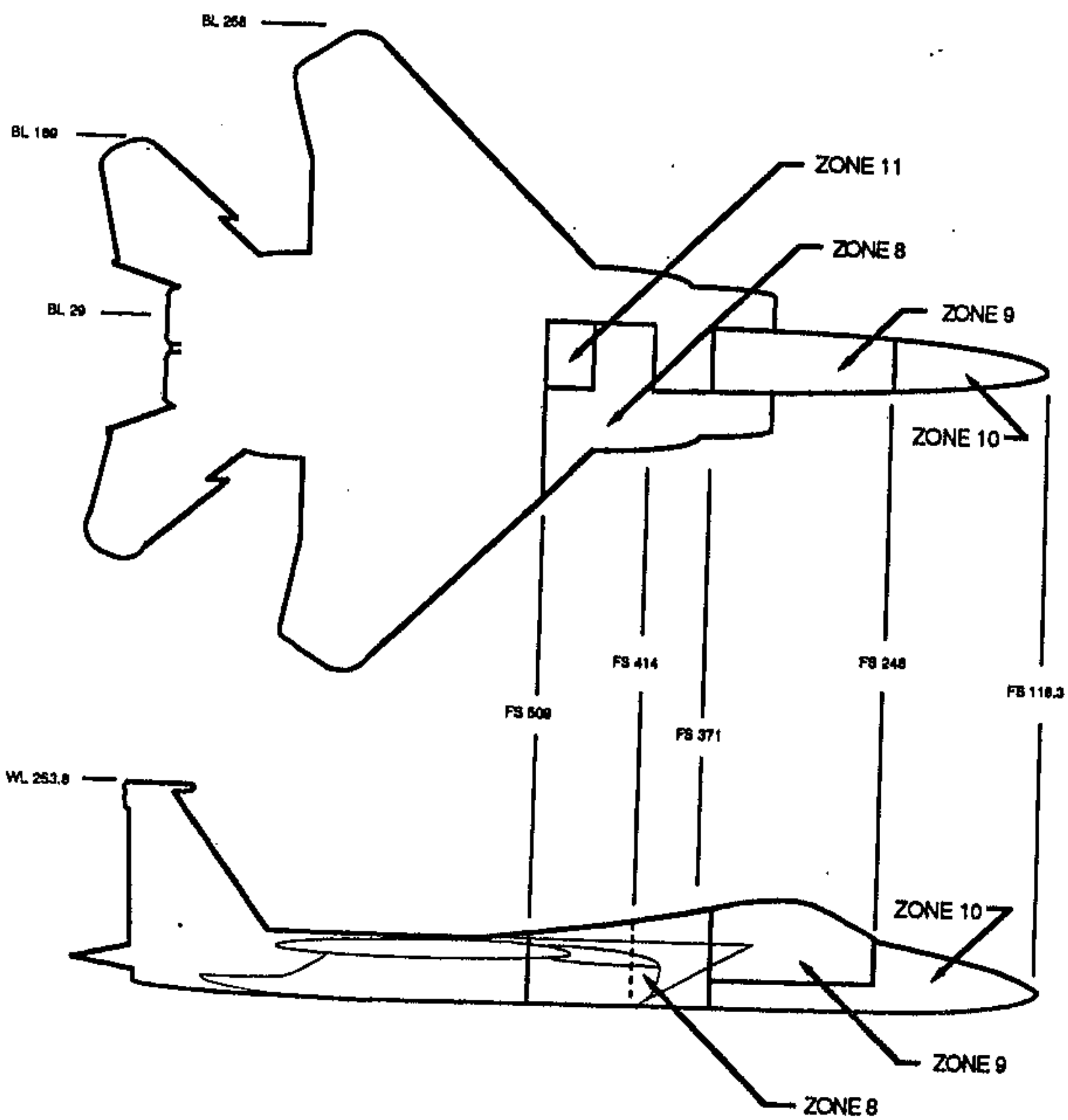


Figure 61
Overall Acoustic Noise Levels
And Frequency Spectrum (Gunfire)

Zone	Description	Overall SPL (dB) Performance 10 minutes
8	Gun Bay /Gunfire Areas	168
9	Cockpit	137
10	Radar and Equipment Bays	144
11	Ammo Bay	164

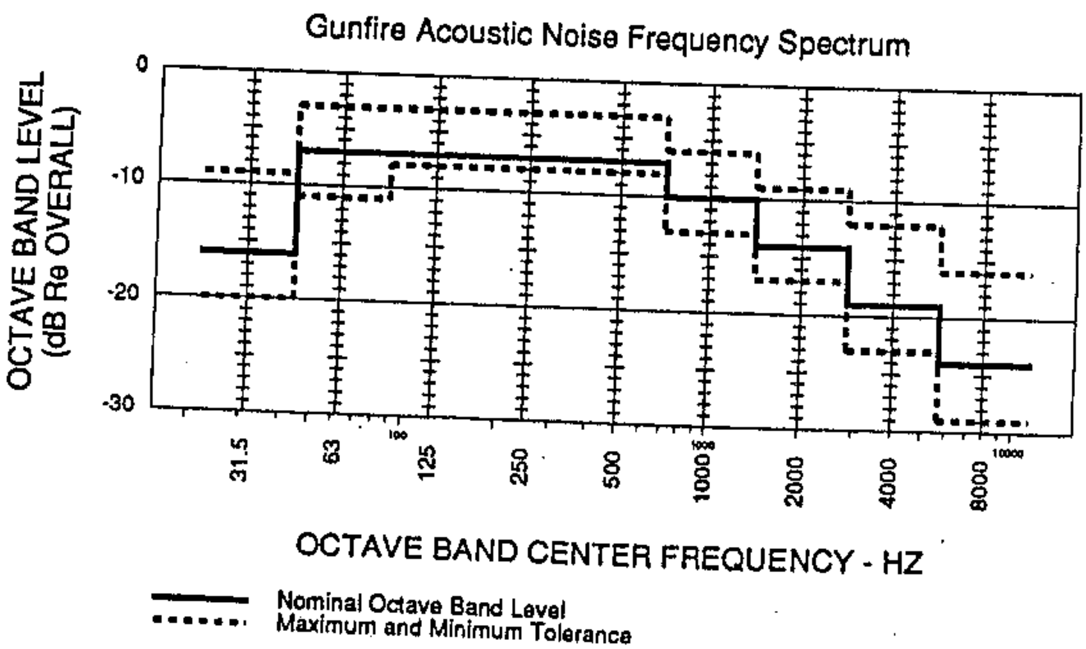


Figure 62
Maximum Allowable Equipment Generated
Acoustic Noise Levels

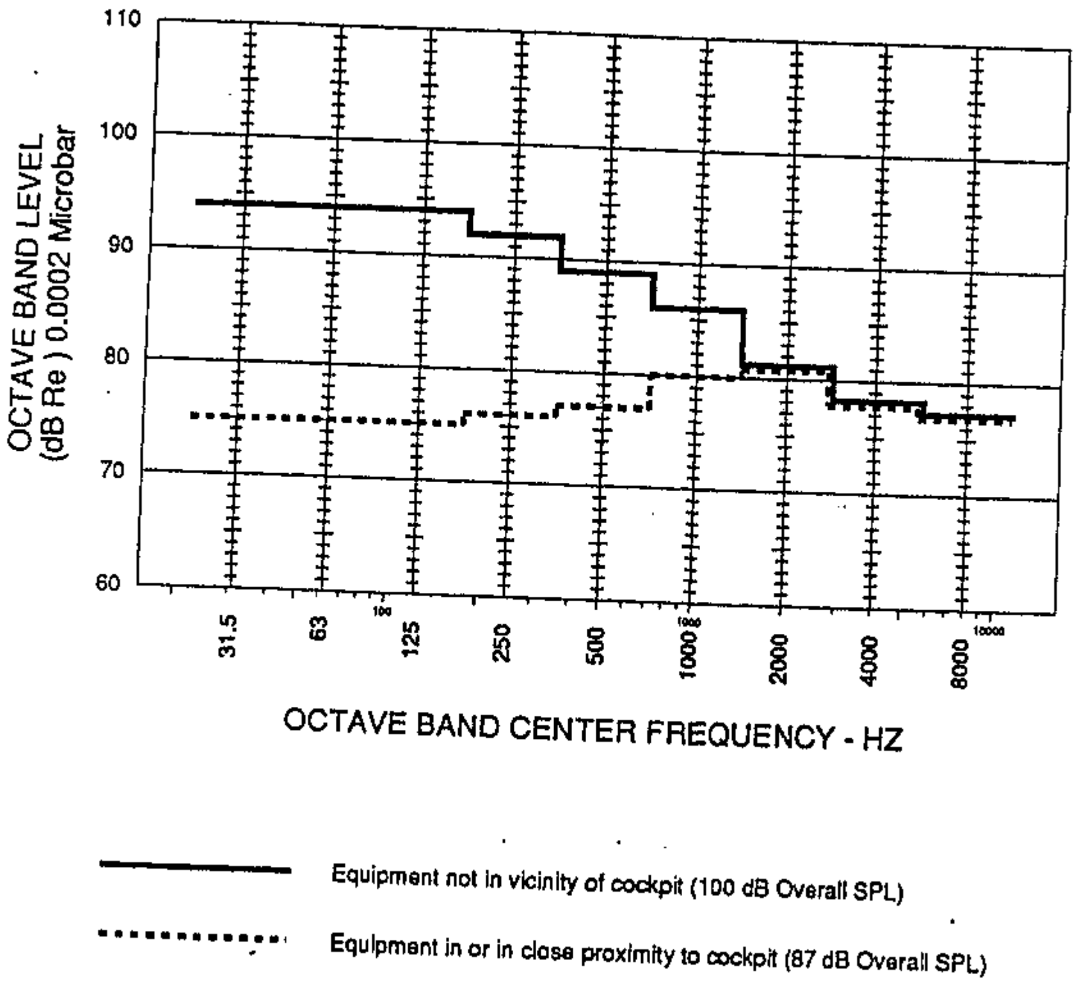


Figure 63
Shock Regions

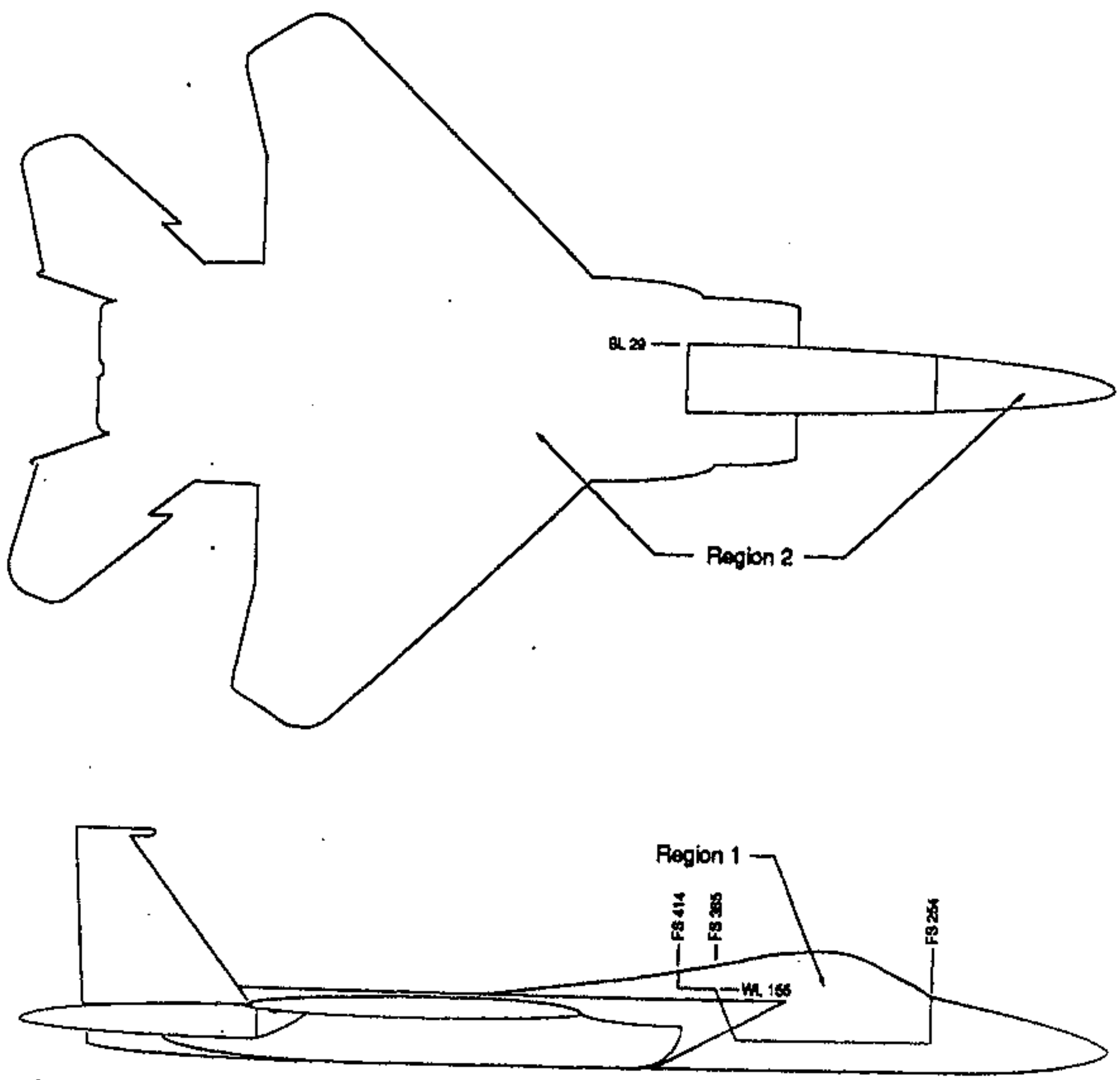
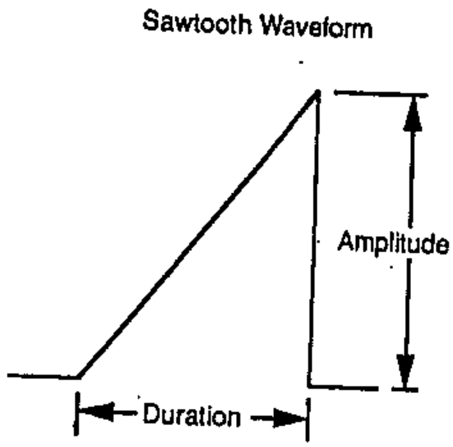
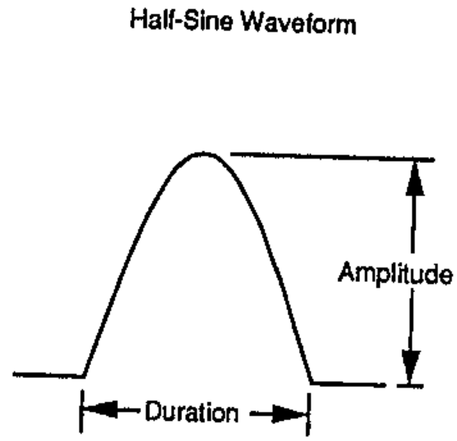


Figure 64
Shock Test Requirements



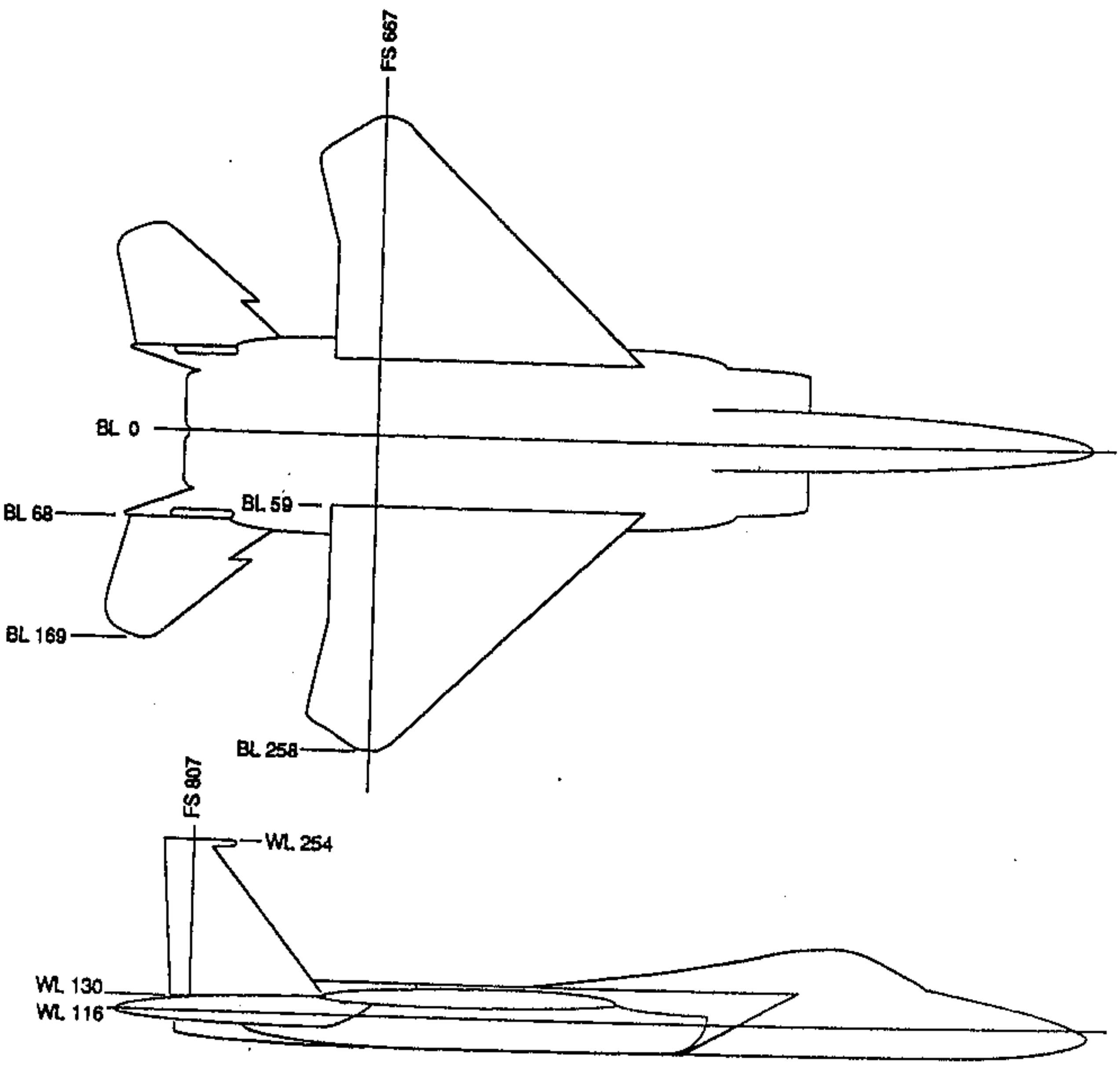


Region	Description	Peak Amplitude in g's (sawtooth/half-sine)	Nominal Duration (milliseconds)
1 Cockpit	a. Service Shock (Equipment Normally Mounted)	20/15	11
	b. Service Shock (Equipment Removed from Resilient Shelf/Panel)	20/15	22
	c. Crash Safety (Equipment Normally Mounted)	40/30	11
	d. Crash Safety (Equipment Removed from Resilient Shelf/Panel)	40/30	22
2 All Areas Except Cockpit	a. Service Shock (Equipment Normally Mounted)	20/15	11
	b. Service Shock (Equipment Removed from Resilient Shelf/Panel)	20/15	22

The peak amplitude must be within ±10% of the specified value.

The duration must be within ±9% (11 ± 1 millisecond or 22 ± 2 milliseconds of the specified value.

Figure 65
F-15 Aircraft Geometry with Locations
Indicated for Load Trends Provided*



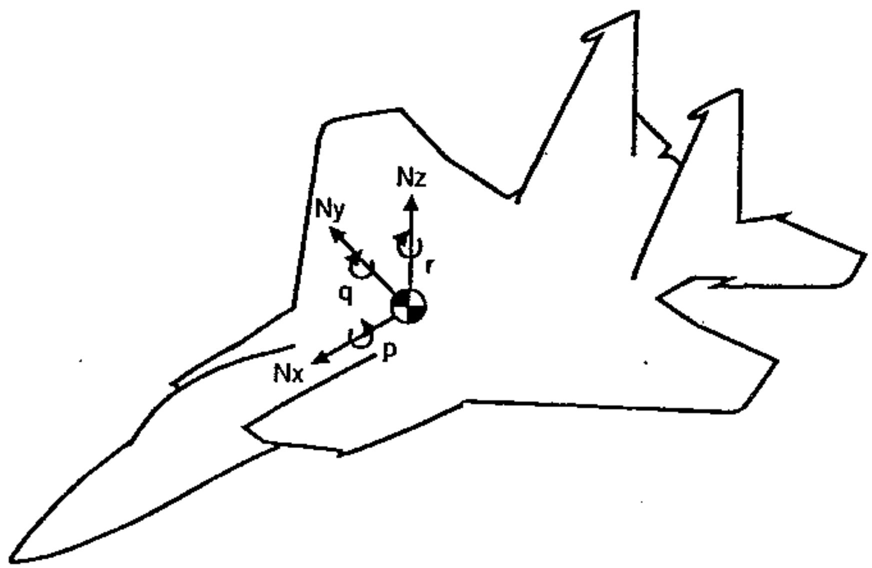
* Trends are provided in Figures 66-71.

Figure 65.1
F-15 Design Load Conditions*

MANEUVER DESCRIPTION	COND	Linear Acceleration (g's) NX	NY	NZ	Angular velocity (radians/sec) P	Q	R	Angular Acceleration (radians/sec/sec) PDOT	QDOT	RDOT
SYMMETRIC LANDING	1	0.00	0.00	2.70	0.00	0.00	0.00	0.00	0.00	0.00
DRIFT LANDING	2	0.00	1.00	1.40	0.00	0.00	0.00	0.00	0.00	0.00
BUMP	3	0.00	0.00	2.00	0.00	0.00	0.00	0.00	0.00	0.00
SYMMETRIC ARRESTMENT	4	-1.30	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
UNSYMMETRIC ARRESTMENT	5	-1.20	0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
UNSYMMETRIC ARRESTMENT	6	-1.20	-0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
TURNING	7	0.00	0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
TURNING	8	0.00	-0.50	1.00	0.00	0.00	0.00	0.00	0.00	0.00
TURNING	9	-0.50	0.30	1.00	0.00	0.00	0.00	0.00	0.00	0.00
TURNING	10	-0.50	-0.30	1.00	0.00	0.00	0.00	0.00	0.00	0.00
CRASH	11	-6.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CRASH	12	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CRASH	13	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CRASH	14	0.00	-1.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
CRASH	15	0.00	0.00	-1.30	0.00	0.00	0.00	0.00	0.00	0.00
CRASH	16	0.00	0.00	3.00	0.00	0.00	0.00	0.00	0.00	0.00
SPIN: STEEP, RIGHT, ERECT	17	0.00	0.00	3.67	3.50	1.00	2.50	0.00	0.00	0.00
SPIN: STEEP, RIGHT, ERECT	18	0.00	0.00	3.67	3.50	-1.00	2.50	0.00	0.00	0.00
SPIN: STEEP, RIGHT, INVERTED	19	0.00	0.00	-2.50	-3.50	1.00	2.50	0.00	0.00	0.00
SPIN: STEEP, RIGHT, INVERTED	20	0.00	0.00	-2.50	-3.50	-1.00	2.50	0.00	0.00	0.00
SPIN: STEEP, LEFT, ERECT	21	0.00	0.00	3.67	-3.50	1.00	-2.50	0.00	0.00	0.00
SPIN: STEEP, LEFT, ERECT	22	0.00	0.00	3.67	-3.50	-1.00	-2.50	0.00	0.00	0.00
SPIN: STEEP, LEFT, INVERTED	23	0.00	0.00	-2.50	3.50	1.00	-2.50	0.00	0.00	0.00
SPIN: STEEP, LEFT, INVERTED	24	0.00	0.00	-2.50	3.50	-1.00	-2.50	0.00	0.00	0.00
SPIN: FLAT, RIGHT, ERECT	25	0.00	0.00	1.00	1.50	0.00	3.50	0.00	0.00	0.00
SPIN: FLAT, RIGHT, INVERTED	26	0.00	0.00	-1.00	-1.50	0.00	3.50	0.00	0.00	0.00
SPIN: FLAT, LEFT, ERECT	27	0.00	0.00	1.00	-1.50	0.00	-3.50	0.00	0.00	0.00
SPIN: FLAT, LEFT, INVERTED	28	0.00	0.00	-1.00	1.50	0.00	-3.50	0.00	0.00	0.00
SYMMETRIC: STEADY STATE	29	0.00	0.00	9.00	0.00	0.00	0.00	0.00	0.00	0.00
SYMMETRIC: STEADY STATE	30	0.00	0.00	-3.00	0.00	0.00	0.00	0.00	0.00	0.00
SYMMETRIC: PULL-UP	31	0.00	0.00	9.00	0.00	0.00	0.00	0.00	-3.60	0.00
SYMMETRIC: PUSH-DOWN	32	0.00	0.00	-3.00	0.00	0.00	0.00	0.00	3.60	0.00
SYMMETRIC: PULL-UP	33	0.00	0.00	6.00	0.00	1.20	0.00	0.00	0.00	0.00
SYMMETRIC: PUSH-DOWN	34	0.00	0.00	-2.00	0.00	-1.20	0.00	0.00	0.00	0.00
SYMMETRIC: MAX DECELERATION	35	-3.00	0.00	1.00	0.00	0.00	0.00	0.00	0.60	0.00
SYMMETRIC: TAKEOFF	36	1.50	0.00	1.00	0.00	0.00	0.00	0.00	0.00	0.00
UNSYMMETRIC: RUDDER REVERSAL	37	0.00	0.60	1.00	0.00	0.00	0.80	0.00	0.00	0.00
UNSYMMETRIC: RUDDER REVERSAL	38	0.00	-0.60	1.00	0.00	0.00	-0.80	0.00	0.00	0.00
UNSYMMETRIC: RUDDER REVERSAL	39	0.00	2.00	1.00	0.00	0.00	-0.50	0.00	0.00	-2.00
UNSYMMETRIC: RUDDER REVERSAL	40	0.00	-2.00	1.00	0.00	0.00	0.50	0.00	0.00	2.00
UNSYMMETRIC: 360 DEGREE ROLL	41	0.00	0.30	1.50	4.70	0.00	0.10	0.00	-0.30	-0.20
UNSYMMETRIC: 360 DEGREE ROLL	42	0.00	0.30	1.50	-4.70	0.00	-0.10	0.00	-0.30	0.20
UNSYMMETRIC: 180 DEGREE ROLL	43	0.00	0.30	-1.00	4.70	-0.10	0.10	-3.90	-0.50	0.00
UNSYMMETRIC: 180 DEGREE ROLL	44	0.00	0.30	-1.00	-4.70	-0.10	-0.10	3.90	-0.50	0.00
UNSYMMETRIC: 180 DEGREE ROLL	45	0.00	0.60	-1.00	2.40	-0.30	0.10	-18.00	-0.30	-0.80
UNSYMMETRIC: 180 DEGREE ROLL	46	0.00	-0.60	-1.00	-2.40	-0.30	-0.10	18.00	-0.30	0.80
UNSYMMETRIC: ROLLING PULL-OUT	47	0.00	0.30	7.20	0.50	0.30	0.40	-18.00	-0.10	0.30
UNSYMMETRIC: ROLLING PULL-OUT	48	0.00	-0.30	7.20	-0.50	0.30	-0.40	18.00	-0.10	-0.30
UNSYMMETRIC: ROLLING PULL-OUT	49	0.00	1.50	7.20	0.90	0.00	0.20	2.30	-0.20	-0.20
UNSYMMETRIC: ROLLING PULL-OUT	50	0.00	-1.50	7.20	-0.90	0.00	-0.20	-2.30	-0.20	0.20
UNSYMMETRIC: ROLLING PULL-OUT	51	0.00	1.00	7.20	4.70	0.00	0.00	0.00	0.00	0.00
UNSYMMETRIC: ROLLING PULL-OUT	52	0.00	-1.00	7.20	-4.70	0.00	0.00	0.00	0.00	0.00

*See Figure 65.2 for a description of the sign convention.

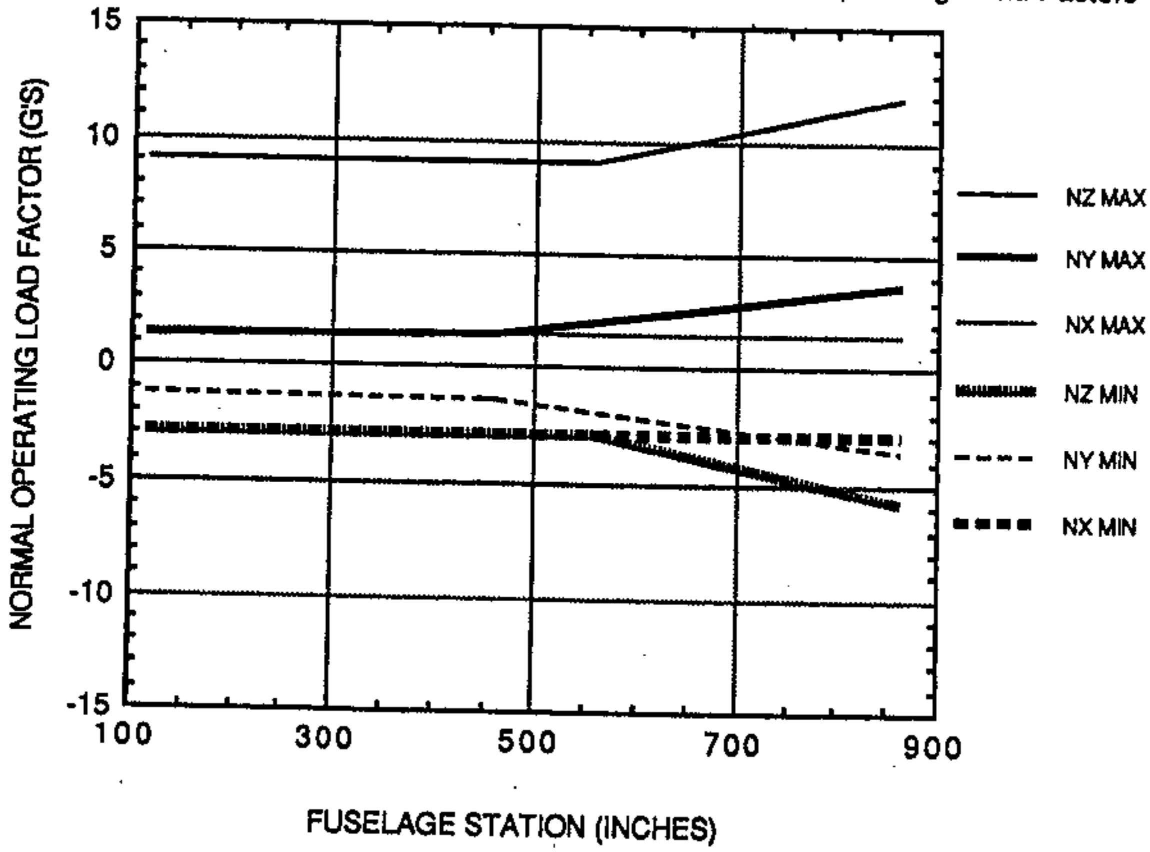
Figure 65.2
Sign Convention for Design Load Conditions
(See Figure 65.1 for Load Conditions)



Nx, Ny, and Nz are positive forward, to the right, and upward, respectively.

p, q, and r are positive angular rates for a roll where the left wing rises, a pitch nose up, and a yaw nose right.

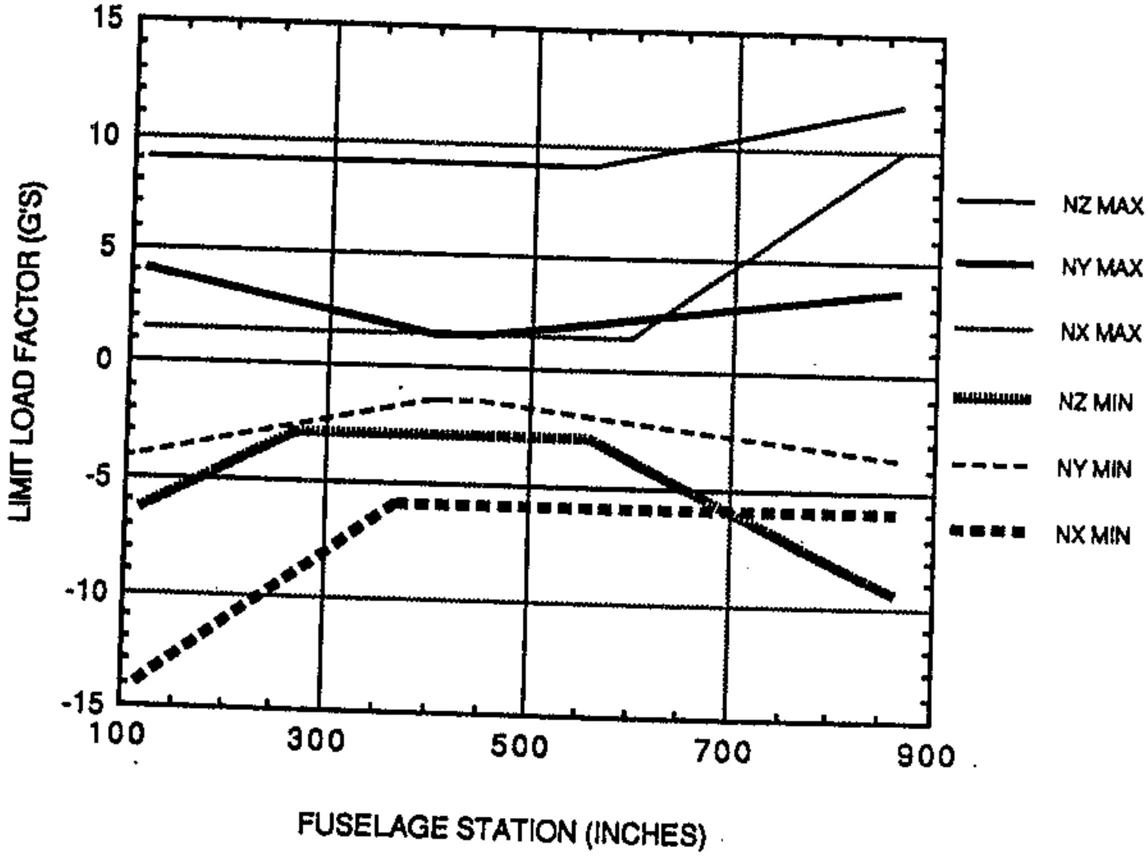
Figure 66
Acceleration Loads Design Requirements
Effect of Change in Aircraft Fuselage Station on Normal Operating Load Factors*



* The load factors shown are for constant WL 116 and BL 0. These load factors may be used only as a design guideline. Loading conditions for qualification of specific equipment items will vary and will be determined as required.

Sign Convention:
- Inertial forces from (+) vertical load factors, Nz, act down.
- Inertial forces from (+) lateral load factors, Ny, act toward the left side.
- Inertial forces from (+) longitudinal load factors, Nx, act aft.
- (+) buttock-line location (BL) is on the aircraft right side.

Figure 67
Acceleration Loads Design Requirements
Effect of Change in Aircraft Fuselage Station on Limit Load Factors*



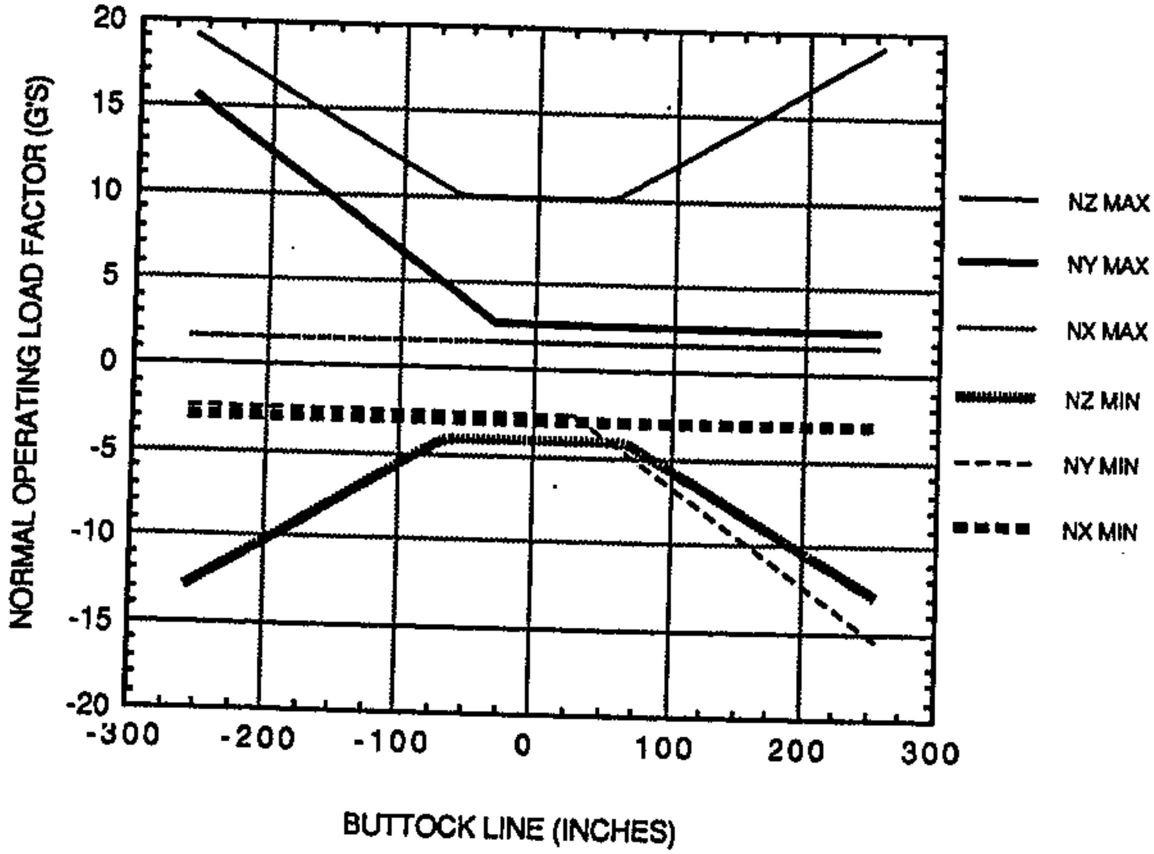
NOTE: Ultimate Loads are 1.5 X the limit loads presented.

* The load factors shown are for constant WL 116 and BL 0. These load factors may be used only as a design guideline. Loading conditions for qualification of specific equipment items will vary and will be determined as required.

Sign Convention:

Inertial forces from (+) vertical load factors, Nz, act down.
Inertial forces from (+) lateral load factors, Ny, act toward the left side.
Inertial forces from (+) longitudinal load factors, Nx, act aft.
(+) buttock line location (BL) is on the aircraft right side.

Figure 68
Acceleration Loads Design Requirements
Effect of Change in Aircraft Buttock Line on Normal Operating Load Factors*

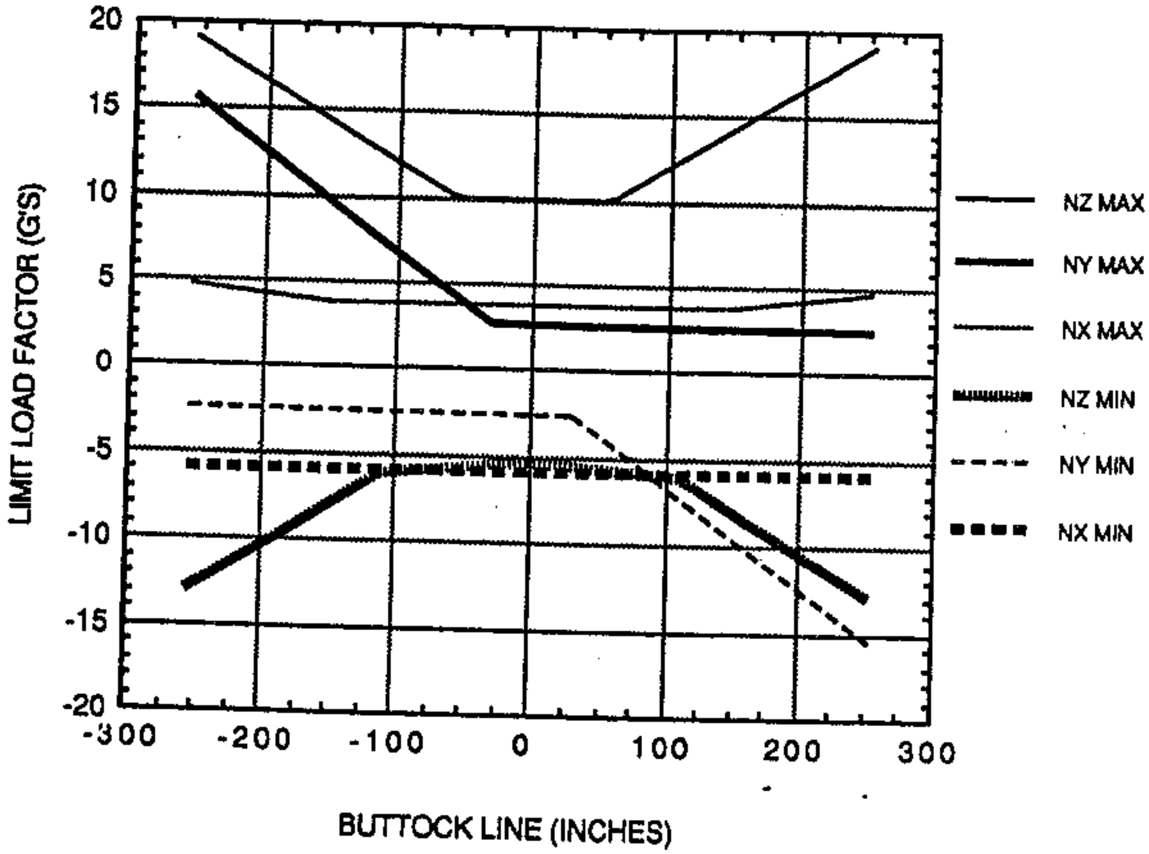


* The load factors shown are for constant FS 667 and WL 130. These load factors may be used only as a design guideline. Loading conditions for qualification of specific equipment items will vary and will be determined as required.

Sign Convention:

Inertial forces from (+) vertical load factors, Nz, act down.
Inertial forces from (+) lateral load factors, Ny, act toward the left side.
Inertial forces from (+) longitudinal load factors, Nx, act aft.
(+) buttock line location (BL) is on the aircraft right side.

Figure 69
Acceleration Loads Design Requirements
Effect of Change in Aircraft Buttock Line on Limit Load Factors*



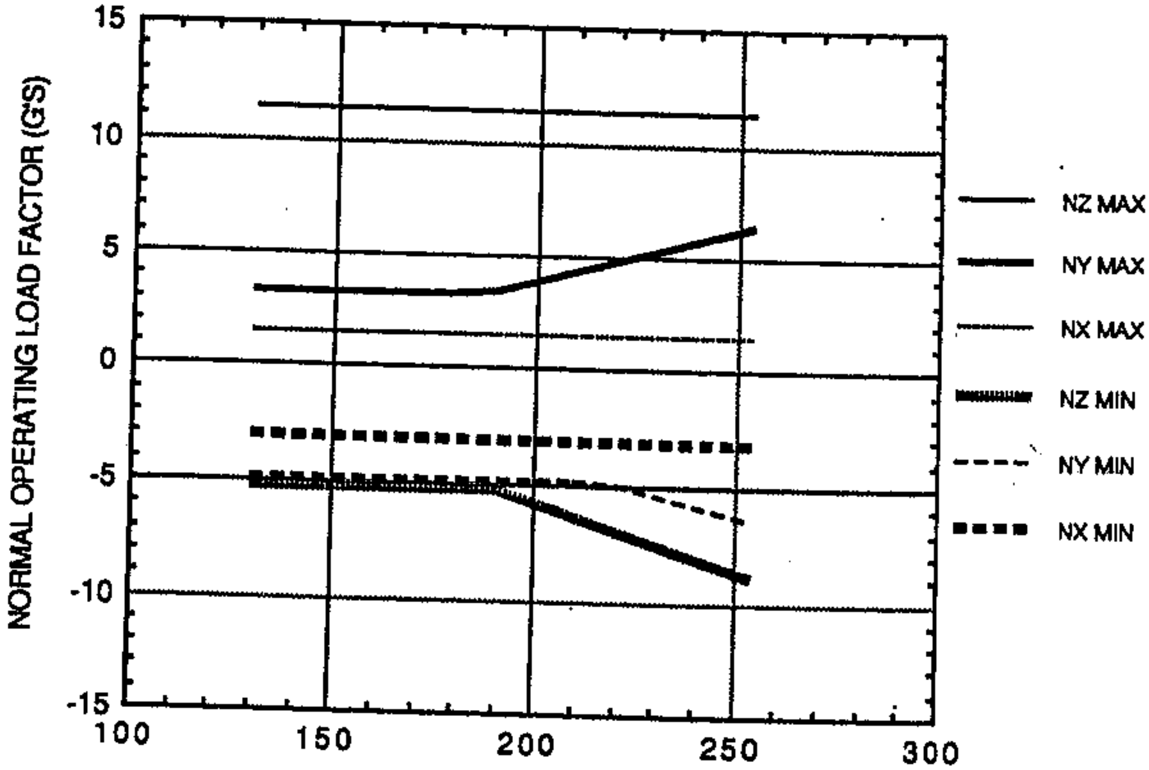
NOTE: Ultimate Loads are 1.5 X the limit loads presented.

* The load factors shown are for constant FS 667 and WL 130. These load factors may be used only as a design guideline. Loading conditions for qualification of specific equipment items will vary and will be determined as required.

Sign Convention:

Inertial forces from (+) vertical load factors, Nz, act down.
Inertial forces from (+) lateral load factors, Ny, act toward the left side.
Inertial forces from (+) longitudinal load factors, Nx, act aft.
(+) buttock line location (BL) is on the aircraft right side.

Figure 70
Acceleration Loads Design Requirements
Effect of Change in Aircraft Water Line on Normal Operating Load Factors*

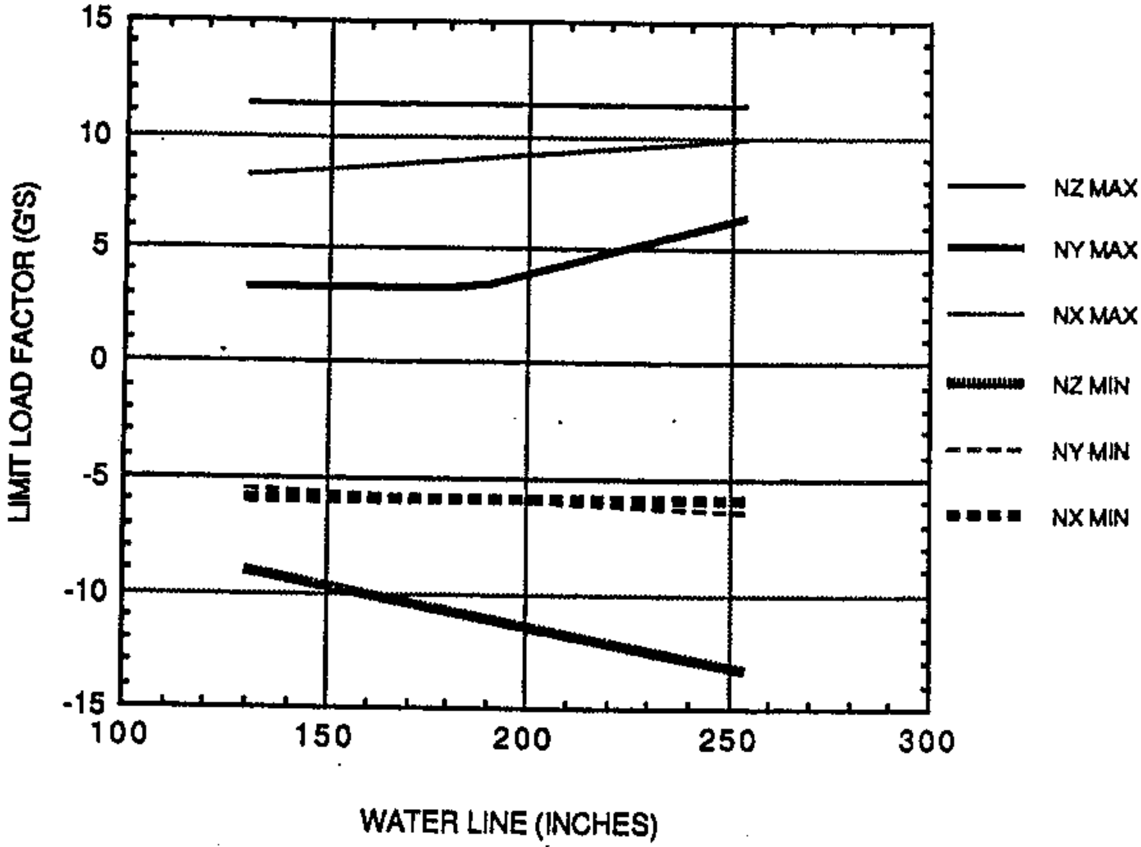


* The load factors shown are for constant FS 807 and BL 68 on the right vertical tail. For the left vertical tail, the Ny max/min values are the opposite sign of the Ny min/max values shown above. These load factors may be used only as a design guideline. Loading conditions for qualification of specific equipment items will vary and will be determined as required.

Sign Convention:

Inertial forces from (+) vertical load factors, Nz, act down.
Inertial forces from (+) lateral load factors, Ny, act toward the left side.
Inertial forces from (+) longitudinal load factors, Nx, act aft.
(+) buttock line location (BL) is on the aircraft right side.

Figure 71
Acceleration Loads Design Requirements
Effect of Change in Aircraft Water Line on Limit Load Factors*



NOTE: Ultimate Loads are 1.5 X the limit loads presented.

* The load factors shown are for constant FS 807 and BL 68 on the right vertical tail. For the left vertical tail, the Ny max/min values are the opposite sign of the Ny min/max values shown above. These load factors may be used only as a design guideline. Loading conditions for qualification of specific equipment items will vary and will be determined as required.

Sign Convention:
Inertial forces from (+) vertical load factors, Nz, act down.
Inertial forces from (+) lateral load factors, Ny, act toward the left side.
Inertial forces from (+) longitudinal load factors, Nx, act aft.
(+) buttock line location (BL) is on the aircraft right side.